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Automation of Military Civil Engineering and Site Design Functions: Software Evaluation

by
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The U.S. Army Corps of Engineers (USACE), which is responsible for all construction in the Army and Air Force, is increasingly taking advantage of computer tools for drafting and design. However, the focus has been on the building design rather than the civil/site designs. As a result, civil engineers are not using automation to the same extent as other architect-engineer (A/E) disciplines.

This report assesses the need for computer software to support civil engineers and evaluates the suitability of products commercially available in FY88 in meeting this need. Only software packages for personal computers were considered. A comparative evaluation was made of products from 18 vendors. The parameters evaluated included system requirements, hardware requirements, functional engineering needs, vendor support, and cost. On this basis, three software packages were selected for further evaluation: CivilSoft, CEAL, and Wescom.

These three packages then were subjected to rigorous benchmark testing to both confirm their performance claims and permit further distinctions to be made among them. As a result of this effort, the Wescom package was found to offer the best overall capabilities. It is recognized, however, that one of the other products might have specific features that would make it more desirable for a particular user.

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This report assesses the need for computer software to support civil engineers and evaluates the suitability of products commercially available in FY 88 in meeting this need. Only software packages for personal computers were considered. A comparative evaluation was made of products from 18 vendors. The parameters evaluated included system requirements, hardware requirements, functional engineering needs, vendor support, and cost. On this basis, three software packages were selected for further evaluation: CivilSoft, CEAL, and Wescom.

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FOREWORD

This investigation was performed for the Directorate of Engineering and Construction, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162731AT41, "Military Facilities Engineering Technology"; Work Unit AO-020, "Site Development." The work was done by the U.S. Army Construction Engineering Research Laboratory (USACERL) Facilities Systems Division (FS). The HQUSACE technical monitor was E. Racht, CEMP-EA.

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1 INTRODUCTION

Background

The U.S. Army Corps of Engineers (USACE) is making extensive use of computer-aided drafting and design (CADD) tools in the architectural/engineering (A/E) community. USACE is responsible for all military construction (MILCON) within the Army and the Air Force; the size and nature of the MILCON program (e.g., use of standard designs) have made automation especially attractive for improving productivity and efficiency within USACE Districts and Divisions. The extent of USACE's reliance on CADD is apparent in the recent Corps-Wide CADD Buy initiative, which was an effort to standardize the automation approach throughout USACE and provide management to a burgeoning inventory of computers.

While the A/Es involved with building design are enjoying the benefits of automation, those responsible for civil/site engineering have seen a surprisingly low move toward computer programs in their work. This trend is partly due to an initial unresponsiveness by software manufacturers in meeting the specific needs of civil engineers and partly to the lack of affordable, yet adequate, hardware. However, the availability of more powerful, lower priced microcomputers as well as the emergence of several sophisticated civil engineering design software packages have now made this technology potentially affordable and efficient to use.

To ensure that design automation is exploited to maximum benefit within USACE, the U.S. Army Construction Engineering Research Laboratory (USACERL) has been asked to investigate the need for civil engineering tools. If it is found that these programs offer a promising advantage over manual methods, USACERL is to evaluate available software to determine which, if any, is best suited to the type of civil design work done in USACE.

Objective

The objective of this work is to evaluate the need for automated civil engineering tools within USACE Districts and Divisions, and to recommend microcomputer software and hardware capable of both meeting that need and interfacing with existing CADD systems.

Approach

To determine the need for civil engineering programs, USACERL surveyed the Districts and Divisions using a questionnaire. When it became apparent that such a need exists, information from the questionnaire was used in developing criteria that a program would have to meet to support USACE effectively. In addition, key management representatives from USACE participated in a steering committee with USACERL to identify the users' needs. Using these criteria, products from numerous companies were assessed on the basis of manufacturers' claims. This evaluation revealed three software

packages that could potentially meet the criteria. These three products were tested in-house at USACERL to verify performance and determine which one(s) would best serve the USACE civil engineer.

Scope

Because of the widespread use of personal computers (PCs) within USACE, only software packages designed for the PC were evaluated. In addition, it should be noted that the software industry is extremely volatile; a product judged as "best choice" at one point in time may soon become obsolete due to rapid developments in the technology. The findings in this report reflect products on the market as of early FY88 and may not represent the state of the art today.

Mode of Technology Transfer

Information in this report is being used to develop field tests of the most promising software. Product(s) tested successfully will be recommended to USACE. Depending on USACE's decision to implement a particular software, USACERL will establish users' groups and support teams for the field.

2 NEEDS ASSESSMENT AND CRITERIA DEVELOPMENT

Engineering Design Questionnaire

The initial step was to determine if USACE identifies a need for civil engineering and site design software. This information was solicited through a survey of the District and Division offices. The survey consisted of a questionnaire designed to ask engineers what type of hardware and software their District/ Division currently has and what they plan to obtain in the near future. The survey specifically asked about the number and types of PCs in use and the interest in site design software. Appendix A shows this questionnaire along with tallied responses. The results are summarized below.

The questionnaire revealed that the Districts already have 300 PCs being used for design work and will probably purchase some 200 more within a year. The trend is toward acquisition of the IBM AT or Zenith (AT-compatible). Districts also use some type of peripheral such as a plotter, mouse, tablet, or digitizer.

The Districts and Divisions are in the process of acquiring engineering software for their PCs. Except for the U.S. Army Waterways Experiment Station (WES) Corps library programs, no one software is being used more than another. For drafting, AutoCAD has been the most commonly used software.

All Districts were interested in obtaining additional software for surveying, earthwork, contouring, road layouts, site planning, utilities, structures, and other civil engineering tasks. This interest was divided evenly, with no one area dominating.

Almost one-third of the District offices were willing to spend only up to $6000 for a comprehensive design package, whereas about two-thirds said they would spend more than $6000. Three of the District offices said they were satisfied with their current equipment and would not buy any additional software.

Eighty-five percent of the Districts were interested in helping evaluate the software.

It was concluded from this survey that the Districts have purchased and will continue to buy a large number of PCs. It was also found that the Districts had a definite interest in obtaining software to support civil engineering/site development on their PCs. Therefore, USACERL continued the investigation by developing criteria for software that would meet USACE's needs.

Criteria for Software Capabilities

Because the Districts all have a substantial number of PCs and need suitable civil engineering software immediately, it was decided to first investigate the available commercial software rather than try to develop a new package. To select and evaluate the numerous software packages on the market, a set of criteria was developed which established the desired capabilities. These criteria can be divided into the following five areas: hardware requirements, engineering functions, system requirements, vendor support, and cost.

Hardware Requirements.

The civil engineering site development software must be able to operate on a PC. The minimum requirements for the PC are: IBM AT or compatible, 640K of random access memory (RAM), 20-Mb hard disk, and enhanced graphics adapter (EGA) color monitor. Digitizing capabilities and a printer and/or plotter are necessary peripherals.

Engineering Functions

The engineering functions desired are those which present the site and then allow it to be altered/improved on line to perform road layout, site grading, improved surfaces, entrance ramps, parking, utilities, and similar functions, as summarized below.

Coordinate Geometry (COGO). A COGO feature allows the inputting and processing of data points that have been defined by rectangular coordinates. Data input is from field survey data or photogrammetric surveys. The site is defined by this coordinate system and this function provides a database as well as a tool for the other engineering functions.

Digital Terrain Modeling (DTM). A two-dimensional (contouring) or three-dimensional (perspective) solid model of the site can be generated from random X, Y, and Z coordinates using DTM. This function should be able to rotate the site model so that it can be studied from any viewpoint, either in its original state or after it has been modified by the design process. The database generated by COGO is used to produce the DTM.

Contouring/Mapping. This function generates a contour map from the DTM or from random X, Y, and Z coordinates. Included in this feature is the ability to digitize the contours from existing maps and generate topographical, planimetric, or other types of overlay maps.

Profiling/Cross Sections. This feature allows automatic generation of profiles and cross sections from contour maps or the DTM at any point on the site.

Road Design. The road design function computes horizontal and vertical alignments showing the completed road design in both the plan and profile views. It should be able to use the COGO database and functions.

Earthwork. This feature computes (1) quantities of material that is either cut or filled and (2) surface areas. An earthwork function computes these required quantities from both the original DTM (or original site conditions) and the new plan generated by the design process.

Geotechnical. This feature displays subsurface material for a project along with the data describing the engineering properties of that substrata. In addition, it performs appropriate design calculations based on the substrata allocation and its corresponding properties. A geotechnical feature is not essential for system startup and should be considered a future desired capability.

Utilities. This feature displays utilities such as storm and sanitary sewers, water, and electricity. Included in this display are profiles showing the invert elevations, slopes, and similar data. This feature is also envisioned as a future enhancement.

System Requirements

The software selected should have its own drafting capabilities or be able to interact, at the PC level, with commercial drafting packages such as the Intergraph Microstation. In addition, drawings produced should be able to transfer to a central CADD system such as Intergraph.

The software package should be able to produce a plot on the monitor (with the ability to enlarge areas of interest) with good quality. These plots should match the quality and resolution of the user's EGA board and monitor. Also, the system should be able to create distinct layers so that only the information pertinent to a particular design phase is shown.

Finally, the software should be user-friendly. All commands used should be easy to follow, prompt for data input, give helpful messages when an error is made, and have an online help screen.

Vendor Support

The vendor must be willing to incorporate new ideas and design tools into the software package and/or modify it to meet USACE's unique needs. The vendor must also provide adequate technical support to answer questions the engineer may have on the practical as well as technical aspects of the software.

Cost

The software package should cost in the range of $10K to $15K per workstation. Compatible hardware should be in this same range.

Site Development Steering Committee

To ensure that the software selected would meet USACE's needs, a Site Development Steering Committee was formed with representatives from USACERL, 11 District offices, and USACE headquarters. One of the first committee actions was to meet and discuss the work to date on this project, including verification of the software criteria described above.

The criteria established by USACERL were discussed, refined, and expanded. The engineering functions COGO, contouring, DTM, road layout, and earthwork were all seen as desired software capabilities. No additional functions were added; however, it was recommended that the road layout and earthwork functions include a minimum of six layers and the software be able to calculate both volumes and areas.

The interactive capabilities were also felt to be very important in the software package. These capabilities were specified to include (1) incorporation of other engineering disciplines, such as overall site planning, structures, geotechnical aspects, and utilities, either into the software itself or by interfacing it with the results of these other disciplines, (2) macro applications (the ability to write small programs within the software), and (3) interface/interaction with other graphic software. The ability to transport data either in coordinates or as a graphic solution is an important qualification to this last item.

3 VENDOR EVALUATION AND SELECTION OF CANDIDATE SOFTWARE

Vendor Identification and Evaluation

Using criteria described in Chapter 2, software products were evaluated by examining the literature from several manufacturers. In addition, professionals from both USACE District offices and the private sector were interviewed for input and vendors were asked to provide demonstrations. Table 1 shows how the software products compared in terms of the criteria. The findings are summarized below for the software packages evaluated.

D.C.A. Engineering Software

D.C.A. software is used to enhance the AutoCAD drafting package and operates solely within the AutoCAD drawing editor. It contains many of the civil engineering functions desired such as road design, profiles and cross sections, and volume computations. It cannot generate contours or a DTM from input points; however, existing contour lines can be digitized. The software is not directly interfaced with a central CADD system such as Intergraph. It is not recommended because of its lack of DTM and contouring.

Geographics/GEOSOFT

Geographics is mainly a mapping software that allows the user to digitize existing contour maps. It has no engineering functions such as road design or COGO but, when coupled with GEOSOFT, it can generate contour maps and compute volumes. It can be interactive with AutoCAD, but cannot be interfaced with a central CADD system. Since it does not have many of the engineering functions desired, it is not recommended.

Design Plus

This software offers many engineering design functions such as road and drainage system design and survey routines. However, to do other functions such as automatic contouring and computer drafting, two other software packages, RETRIEVER and VersaCAD, are needed. As of this evaluation, Design Plus does not have a screen plot or true DTM and it appears that, to be effective, the program must have the other two packages just mentioned.

C & G

C & G software is intended for surveying functions only. It has no DTM, contouring, road design, or other engineering functions. Therefore, it is not recommended.

CONCAP

CONCAP is a software package that appears to be very effective for COGO and road layout. However, it has no automatic contouring or DTM capabilities, nor does it appear to be capable of interfacing with a central CADD system, although it can be converted to AutoCAD. Its strong point is the survey and construction layout of plans, while it is weak in overall plan design.

Table 1

Software Evaluation Matrix*

Software Capabilities	WESCOM	CLM/CEAL	CIVILSOFT	AUTOCOGO/MAP	PLUS 3	AROSE	CONCAP	MTI	DESIGNPLUS	GEOGRAPHICS	DCA	Z PENNOCK	C&G	INTERGRAPH	PACSOFT	McDON DOUG/GDS	COMPUTERVISION
PC BASED	X	X	X	X	X	X	X	X	X	X	X	X	X			A	
SCREEN PLOT/GRAPHICS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
COGO	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X
CONTOURING/MAPPING	X	X	X	O		X		X		X	X			X	X	X	X
ROAD LAYOUT	X	X	X		X		X	X	X		X			X	X	X	X
DTM	X	X	X			X								X	X	X	X
EARTHWORK	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X
PROFILING/X-SECTIONS	X	X	X	O	X	X			X		X			X	X	X	X
UTILITIES		X	X		X				X		X	X		X	X	X	X
INTERFACED W/CAD SYS.	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X
MANAGEMENT CAP.	X	X														X	
LAYERS OR SIMILAR	X	X	X	X							X			X	X	X	X
SUPPORT	X	X	X										X	X	X	X	X

X = Included, good. O = Future products. A = Can be accessed by PC, but software on DEC hardware only.

*Based on literature search with telephone confirmation. This matrix was created before the task study group meeting of May 1987.

MTI Software

MTI Software is a series of packages addressing individual engineering functions such as surveying, road layout, drainage, and earthwork. Contouring is available, but only through a product from another software company. Data input is via the keyboard, with no digitizing capabilities. The largest drawback to this software is that it is not a comprehensive package. Data must be entered for each module of software, with no common database.

PacSoft

PacSoft is a comprehensive software package that appears to meet the criteria except for two of the most important features: ability to run on a PC and interface with a central CADD system. The only PC supporting it is the HP9000. Therefore, this software package was rejected.

PLUS III

This software offers many of the desired engineering functions such as COGO, earthwork, roadwork, and utilities but it does not do contouring or DTM. It is not a comprehensive package, meaning that data must be entered for each module of software. It can link with AutoCAD with special software but cannot interface directly with a central CADD system.

AutoCOGO/MAP

AutoCOGO works entirely within AutoCAD and meets only the COGO criterion. It has no other engineering functions such as road design, although a later release of this program is supposed to include some. It cannot generate contours automatically; however, a third-party vendor such as AutoMAP can supply a package to perform this function and the output can then be used by AutoCOGO. Because AutoCOGO lacks many.of the desired engineering functions at this time, it is not recommended.

Z Pennock

This software meets only the COGO criteria and cannot perform many of the other functions such as road layout, DTM, and contouring. In addition, it cannot interface directly with a central CADD system, and is therefore not recommended.

Arose

Arose software is primarily a tool for creating digital terrain models and calculating earthwork from the data provided by these models. Although it can digitize existing contours, it has no COGO feature and also lacks the ability to do road and utility design layout.

Computervision

Computervision is a very comprehensive site civil engineering development package that meets all of the desired engineering criteria. However, this software can be used only on a mini- or mainframe computer; it is not PC-based.

Intergraph

Intergraph meets all of the desired engineering criteria but, at this time, it can be used only on a mainframe computer and not on a PC. A software package available called the Bentley Systems is 100 percent compatible with the Intergraph and runs on the PC. However, it is mainly drafting-oriented and does not contain the civil/site engineering functions that Intergraph has.

McDonnell Douglas/GDS

This software is very comprehensive in meeting all of the desired criteria, except that it is not PC-based. Although the software can be accessed by a PC, it can only be stored on DEC hardware, raising the cost to operate.

CivilSoft

CivilSoft's product has most of the engineering functions, but is not a comprehensive package. It contains engineering software modules that do not share a common database. Its strong point is COGO and contouring; however, it cannot automatically generate cross sections from data-based contours or triangulation files. It also lacks good roadway design and earthwork computation modules, although these functions are currently being developed, according to the manufacturer. It can interface with AutoCAD, but not with a central CADD system.

CEAL

CEAL is a comprehensive site civil engineering software package that has all of the desired engineering functions except for DTM. This software will digitize existing contour lines and automatically generate contours from random X, Y, and Z coordinates. Although a contour map can be generated, CEAL cannot produce a DTM perspective of the area in question. The vendor does recommend a third-party product that will generate contours and guarantees that the results will be compatible with the CEAL software. CEAL has a good COGO module for inputting and processing data; the data are stored in a common database that is used by the other engineering functions. Operations such as profiling, cross sectioning, road design, and earthwork volume computations can all be performed by the software. It has internal CADD capabilities, although it can also be interfaced with commercial software such as AutoCAD or with a central CADD system. It can .produce finished drawings directly on the PC without requiring touchup from a draftsman.

Wescom

Wescom is a comprehensive software package that addresses all of the desired engineering functions and criteria. The strong point of this software is the automatic generation of contours and a DTM from random X, Y, and Z coordinates. It also can define multiple layers by generating new DTMs and compute volume between the layers. This software uses a common database for all related engineering functions and, therefore, the data are entered only once—from the keyboard or by digitizing. Wescom can also interface with AutoCAD as well as with other CADD systems. This software has programming tools that allow the user to write programs to interface with Wescom.

Selection of Candidate Software

After evaluating the products carefully, it was determined that three—CivilSoft, CEAL, and Wescom—most nearly met the engineering criteria established. To evaluate pricing, hardware and software costs were estimated. The hardware cost, which would include the computer, monitor, and digitizing tablet, would be about $9K. If a central plotter and digitizing tablet is included, the additional cost would be about $10K. The software costs for CivilSoft, Wescom, and CEAL are $6K, $10K, and $13K, respectively (Wescom's and CEAL's costs include training).

At the Site Development Software Committee meeting mentioned in Chapter 2, it was decided that all three of the software companies should be tested in-house at USACERL. Testing at the Districts was discussed; however, the steering committee decided that this might not be a fair initial evaluation because of the different types of work the Districts perform. USACERL would perform benchmark tests on the software first; successful product(s) would then be tested at the District level.

4 BENCHMARK TESTING

As described in Chapter 3, the three software packages to be tested at USACERL were CivilSoft, CEAL, and Wescom. Appendix B shows the test plan. All tests were performed on software current as of March 20, 1988, including CivilSoft version 2.00 and CEAL version 5.12. Wescom versions are numbered differently according to routine function. The findings in this chapter are reported for only those versions and do not reflect any vendor modifications since their release.

Testing Procedure

The benchmark testing was divided into two parts (Appendix B). Part 1 involved inputting electronic data from a floppy disk (provided by Steering Committee Members from Sacramento District) into the software package, creating a contour map, and comparing it with the as-built grading plan provided along with the data. X, Y, Z data were provided along with point numbers and a point code, all in a fixed field format.

Part 2 consisted of using the software to execute a test problem. The problem had been developed by seven of the Districts represented in the steering committee. It involves duplicating the site design for an automated data processing (ADP) building site at Fort Irwin, CA. The site design, roughly 450 by 600 ft, included a raised, irregular-shaped building pad, parking lot, service drive, drainage swale, drainage ditch, and access road. The software was tested for how well it could accurately reproduce the design solution and its respective earthwork volumes.

The sample problem provided had four drawing sheets that were to be duplicated. These sheets included the as-built paving and grading plan, site plan, utilities plan, and cross sections.

Surface data consisted of original contours and field elevations noted on the paving and grading plan. Although it should have been possible, it was found impractical to digitize existing contours using any of the software packages without a digitizing tablet large enough to minimize the number of times the drawing had to be moved. Therefore, original surface data were assembled by scaling the northing and easting distances of field elevations and entering them manually into a data file.

The Wescom, CivilSoft, and CEAL software packages were all tested using the sample problem. The software was tested for performance in the desired capabilities as defined in Chapter 2. Appendices C through E give details of the tests for Wescom, CEAL, and CivilSoft, respectively. This chapter summarizes the results for comparison.

Software Features: General Comparison

Software Content

Wescom software consists of separate routines that may be combined in a batch procedure. Components are organized into three general areas: core routines, surveying routines, and engineering routines. All routines, regardless of general classification, can be combined with any other routine in a batch file.

Because Wescom does not provide for text editing, a separate text editor or word processing program capable of handling ASCII* format is needed. Wescom provides its own plotting routines.

CivilSoft software is composed of distinct packages that can be purchased and used without the others. Packages purchased and tested include: Cogo-PC Plus, Highway Design Program, Contour, and Digiplus. CivilSoft's Collect package was not tested. Each package contains a set of possible commands that can be combined to form a batch file. Batch files can be run only in the package in which they were created; it is not possible to combine files from separate packages. CivilSoft provides its own plotting routines and a text editor.

CEAL is a command-driven, integrated software package. Commands are organized by the categories COGO, Topo, Roads, Grafx, and Link. To supplement the CEAL software, Carta software produced by IDAN Computers, Inc., can be used for additional terrain analysis—more specifically, to create and integrate the triangulation network used to interpolate contours from general X, Y, Z data. To meet USACE's needs, CEAL must be used in conjunction with Carta. Both CEAL and Carta use the same commands. These commands are entered and processed at the same time, making batch routines unnecessary. However, CEAL will store all commands used in a program file, allowing the user to alter and rerun an entire set. Program files can be edited using CEAL's own text editing routine. CEAL provides commands to produce hard copy plots and prints independently.

Pricing

Wescom software is distributed on floppy disks, either 360-Mb or 1.2-kb. The price of the software alone is $8K. Training, performed at USACERL, is priced at $3K, for a total of $11 K.

CivilSoft Software is distributed on 360-Mb floppy disks. The cost of its software packages are:

Digiplus	$ 290
Cogo-PC Plus	$2390
Contour	$1290
Highway Design Program	$1690

Training, performed at the place of installation, costs an additional $3K, for a total price of $11,270.

CLM's CEAL Is distributed on either 360-Mb or 1.2-Kb floppy disks or on tape. Cost of the software, including both CEAL and Carta, is $12K. Training is performed at the installation site and is $3K, bringing the total to $15K.

Licensing Agreement

Wescom requires a separate site license for each physical location where the software will be used. Within the same physical location, a Right-to-Copy agreement can be purchased, allowing another copy of the software to be made at 25 percent the original cost.

*American Standard Code for Information Interchange.

CivilSoft offers a discount schedule to users desiring to use the software on more than one system. The first copy is offered at full price. The second copy is offered for 75 percent of the full cost. The third through ninth copies can be purchased for 50 percent full cost, and any copies beyond the ninth are possible for 40 percent of the original price. CivilSoft is distributed with a hardware lock which is required to produce output. (Note: recent CivilSoft literature indicates that later versions have no hardware lock.)

CEAL also has a discount schedule for users requiring operation on more than one system. The first copy is offered at full price. Further copies can be purchased for 50 percent of the original cost. CEAL is distributed with a hardware lock which is required for output.

Hardware Requirements

To run Wescom software, the minimum system configuration includes an IBM AT or compatible microcomputer with:

- 512-Kb memory - required
  (640-Kb memory recommended)
- Hard disk—30 Mb or larger - recommended
- 80287 Coprocessor - required
- Floppy disk drive - required
  (1.2 Mb recommended)
- Graphics screen - required
  -Black and white
  -Color graphics adaptor (CGA) or (EGA)
- Printer for 132 columns - required
- Plotter - required for plotting
- MS-DOS 3.0 or later version - required
- Text editor/word processor - recommended
  Digitizing tablet - required for digitizing.

To run CivilSoft, the minimum system configuration includes an IBM-PC (XT or AT) or 100 percent compatible microcomputer with:

- 512-Kb memory - required
  (640-Kb memory recommended)
- Floppy disk drive - required
- 30 Mb hard disk - required
- PC-DOS or MS-DOS 2.1 - required*
- 80-Column printer - required
- Graphics screen
  - Monochrome or color - required
  - Graphics adaptor card - optional
- 80287 Math coprocessor - recommended

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*Note: later releases require MS-DOS 3.0 or later version.

- Pen plotter - required for plotting
- Epson dot matrix printer - for scaled printer plots
- Digitizing tablet - required for using Digiplus.

The minimum system configuration to run CEAL software includes an IBM-PC (XT, AT, personal system 2) or 100 percent compatible with:

- 640-Kb memory - required
  (8-Mb memory - recommended)
- 10 MB hard disk - required
  (30 MB hard disk - recommended)
- Floppy disk drive - required
- 80287 Math coprocessor - required
- IBM, DOS version 3.1 or higher - required
- Graphics screen EGA - required
- Pen plotter - required for plotting
- 132-Column printer - required
- Digitizing tablet - required for digitizing.

Installation Procedure

To install the total Wescom package, approximately 10 Mb of free space on the hard disk is required. The program is installed via an installation batch file provided on a Wescom installation disk. The system autoexec.bat file must be updated to provide a path for the directories created during the installation procedure. The config.sys file must also be updated. It is recommended that a text editor or word processing package be added to Wescom. It was found that after loading Wescom software and installing the SideKick text editing system, 504 Kb of RAM remained free. Wescom operated unhindered with this amount of free RAM. The hardware configuration is defined with parameter files that set the configuration of the monitor, plotter, and printer. Users can alter these files for their own hardware configuration.

To install the four packages of CivilSoft software mentioned above, approximately 1 Mb for each program, or a total of 4 Mb free space on the hard disk is required. The programs are placed in service via installation batch files provided with each package. These batch files create and load the software into different directories. Device drivers are copied into the directories of each program. The drivers are specified through a batch file called Sdriver. The config.sys file must be updated to CivilSoft specifications. It was found that after loading CivilSoft and installing the SideKick text editing system, 490 Kb RAM remained free. CivilSoft was not able to operate with only this amount of free RAM. However, since CivilSoft has a procedure for creating batch files, it was not necessary to use a separate text editor.

Installation of CEAL requires a minimum of 10 Mb free space on the hard disk. The software is installed by implementing the system "install batch file." During installation, Autoexec.clm and config.clm files are created. These files contain updates that must be added to the system autoexec and config files. During installation, the user must allocate the desired amount of extended memory for CEAL operations and specify a drive dedicated to the extended memory. Hardware device configuration is achieved by implementing the Setceal command after loading has been completed.

Training/Support

Training for Wescom was conducted at USACERL in Champaign, IL, by CADDCENTERS in Indianapolis, IN, a regional marketer of Wescom software. Instruction consisted of 3 full days' intensive hands-on training followed by periodic daylong consultations. Training visits occurred roughly once a week for the first month, and once every other week for the next 2 months. In addition, support by telephone was provided at no extra charge. All questions were answered immediately or at the next training visit. Wescom also provides a bug/enhancement form for reporting errors in the software or requesting an update or addition to the software or manuals. Responses to forms submitted during the test were received at different intervals, depending on the complexity of the request or error.

CivilSoft training at USACERL was presented by a CivilSoft consultant and instructor from Pasadena City College, CA. Training consisted of five 8-hr days of intensive training. Most instruction focused on the COGO-PC PLUS and Contour packages. Very little time was spent on the Highway Design package due to its recent release. Telephone support was provided free for a 90-day period after purchase. CivilSoft offers a service that entitles the user to telephone support; it costs $295/yr for the first package and $100/yr for additional packages. This fee includes a maximum of two package updates per year. If the user does not purchase the support service, it is CivilSoft's policy to charge $50 per telephone call.

CEAL training was conducted at USACERL by the manufacturer, CLM/Systems, Inc. of Tampa, FL. Training involved three 8-hr days of intensive training. The focus was on commands driving the Coordinated Geometry and Output functions. Relatively little time was spent covering commands in the Topo and Roads categories. No instruction was presented on Carta software since it had not yet been received by USACERL at the time of training. Telephone support after training was provided at no extra charge.

Batch Procedures

Wescom software is composed of many separate modules. Each module is a program itself and can be run separately or combined with other programs in a batch process. Modules are generally strung together in a rational manner to produce a certain endproduct. For example, routines creating cross section, profiles, templates, and end area volumes are generally combined since all parts contribute to the final plan. Batch files are written using any text editor or word processor and are stored as ".job" files. There is no limit to the number of routines each batch file can contain. Batch files are run by the Wescom Job routine. All of the file or consecutive parts can be run. Output can be sent to the screen or saved in an output file for further reference. Plot files, along with any other files specified in the routines, are created and saved in the current directory. Wescom provides mask files that prompt the user for input and example files to serve as a reference when the user is creating batch files.

CivilSoft contains four distinct components: Contour, COGO-PC PLUS, Highway Design Program, and Digiplus. All four work independently of each other, with each containing its own hardware drivers. Batch files can be created by Civilsoft's text editor in COGO-PC PLUS and in the Highway Design Program. The contour package creates its own batch files by prompting for responses from a menu. Batch files are processed by a different command in each component. No further files are created during batch procedures. At the end of each batch procedure, CivilSoft prompts for the desired form of output. Output can be generated only at this time.

CEAL software contains more than 1200 command-driven programs. Commands are generally entered and processed one at a time. A "history" file is created to record all commands entered since the beginning of the project. History files or portions thereof can be altered and/or rerun and saved as a program file. These program files are edited through CEAL's editing program. Plotting commands can be added directly to the program file. There is no set order in which commands must be entered, although many of them must be preceded by other commands. There are also no set programs to lead the user through program files construction for creating an endproduct. To obtain an endproduct, the user is encouraged to reference flowcharts that give the general directions on which command categories to enter and in what order.

Input

Wescom software accepts data in a variety of forms, including electronically in X, Y, Z or surveying format, or as digitized data. This software accepts data in fixed fields, allowing the user to define which data is in each field. This feature allows the user to avoid changing long lists of data to different fields and to change one field definition line instead. Digitizing data from existing contour maps is also allowed. The user can define into which field he/she would like the digitized x and y coordinates to go along with which field he/she wishes to input the z coordinate or any other data. It was found that digitizing data on a 12 by 12 in. tablet was possible, but clumsy. Large digitizing tablets that allow the user to digitize a complete map without moving the drawing are recommended if extensive digitizing is to be performed.

CivilSoft requires data to be in a specific order but not a specific field. It does not allow the user to define what data are in which field. CivilSoft accepts easting, northing, and elevation data, along with point numbers and description. Any other data, including point codes, will cause the program to terminate. CivilSoft will screen easting, northing, and elevation data; however, it is not possible to screen and omit undesired data based on other point code information. Data can be digitized from existing contour maps using CivilSoft's Digiplus program. Similar to the other packages, it was found that digitizing data on a 12 by 12 in. tablet was possible, but cumbersome.

CEAL accepts a variety of data in X, Y, Z format or electronic survey format. Data in X, Y, Z format must be set in specific fields. Data which are in the correct format can be transferred to other formats used by CEAL in creating different models such as contours and triangulations. It is not possible to screen data in CEAL to eliminate undesired points. Data can be digitized from existing contour maps; however, CEAL requires a large digitizing tablet and a minimum 12-button puck.

Output

Wescom provides its own means for output through a routine called pview. Plot files can be viewed on a monitor or sent to a plotter while in Wescom. In addition, plot files can be transferred to AutoCad drawing files through DXF format. Output produced in text form may or may not be saved to a file. If not, it is printed on the screen or directed to a printer as the batch file is processed. If it is saved to a file, it can be viewed on screen if desired or sent to a standard text printer.

CivilSoft allows output to be plotted after processing a batch routine. Plots can be sent to a graphics display or a pen plotter. Files also can be transferred to DXF file format for AutoCad production. Output produced in text form is saved in an outfile. The outfile can then be viewed on screen or printed on a standard text printer. (Note: CivilSoft literature indicates that later releases are transferable to IGES format.)

CEAL contains its own plotting commands and is supported by a variety of graphics output hardware. Plots can be viewed on a monitor or sent to a plotter while operating CEAL. Plot files can also be transferred to DXF format. In addition, CEAL will transfer plot files to IGES format.

Processing Speed

The software test was performed on Compaq 386 computers with 80287 coprocessors operating at 16 MHz. Key factors in processing speed are site size and the number of data points. The ADP site design covered an area roughly 440 by 600 ft and contained 88 data points.

The procedure requiring the longest processing time in Wescom was the creation of a mesh file. On the ADP site design problem, a mesh file was created from original site data using 3-ft mesh intervals. This operation resulted in a mesh approximately 254 by 126. The maximum number of mesh intervals allowed in Wescom in 256 by 256. Processing time for creating a mesh file was approximately 54 min. A profile and cross section generation with earthwork quantities took about 2 min. Wescom's batching procedure allows the user to set up a batch file and process a routine without being present, making it possible to process large projects overnight.

Using CivilSoft, it took about 1 min to generate a triangulation network and contours for the ADP site design problem. Processing time for a profile and cross section with earthwork quantities was about 2 min. Original surface cross sectional data had to be entered into the batch file manually.

CEAL took less than 1 min to process the triangulation network and contour models from original site data. Processing time for a profile and cross sections with earthwork quantities was about 4 min.

Reference Manual Organization

Wescom provides three reference manuals with its software. These documents cover core software, surveying software, and engineering software. The core software manual contains information on general operations of Wescom software, including input and output. The surveying software manual is dedicated to COGO and related routines, while the engineering manual focuses on earthwork and roads. Each manual is organized by Wescom routines, with each routine tabbed as a new section. Routines are described briefly, followed by a list and explanation of commands needed to create a batch file required to run that routine. Many sections end with an example batch file created for that routine and a sample of the output.

CivilSoft software provides a reference manual with each of its software packages. Manuals correspond with the software component they reference and are titled HDP, COGO-PC PLUS, Contour, and Digiplus. Digiplus describes digitizing input. The contour manual focuses on creating contour maps from user input. the COGO PC-PLUS is a guide to all COGO commands, and the HDP manual explains the commands needed for highway design, sectioning, and volume calculations. Manuals are organized by categories of commands, e.g., HDP's categories include input/output control, definition commands, calculation commands, tutorial section, and plotting commands. Each section is then subdivided into individual commands. Commands are described briefly and user options available with each command are listed. A brief example of each command is given along with sample output.

CEAL reference material consists of five manuals, with installation and operation documents provided separately. Manuals are titled Training, Link/Elf, COGO, Topo/Roads, and Grafx. The training manual provides a set of example problems along with startup procedures and basic beginning information.

Link/Elf contains information on electronic data input and digitizing. COGO explains the commands used for COGO functions. Topo/Roads provides guidance on contouring, sectioning, earthwork volumes, and highway design. Grafx explains how to use all plotting commands. Manuals begin with a section describing the procedures that should be used with the commands listed in the manuals along with general information about all commands. Flowcharts are provided describing the order in which commands should be issued. Commands are explained briefly, followed by a list of user options and descriptions. Examples of input and output are sometimes given.

Performance on Selected Capabilities

In addition to comparing the software products' general performance in the areas identified, other parameters were specifically evaluated. These areas, identified by District Engineers, are considered important to a civil/site engineering package based on experience with CADD software. The features are compared below.

Multiple Alignments/Template Translation

Wescom horizontal alignments are set up using COGO. Alignments, specified as traverses in COGO, can be placed in any arrangement within the boundaries of the mesh file. Templates are assigned to the horizontal alignments in a separate routine. Only one template can be assigned to a horizontal alignment per routine. Multiple horizontal alignment is possible through template transition. Wescom provides for horizontal transitions by variable interpolation. It is thus possible to define one template that reflects changing road widths. Multiple vertical alignment also can be done by variable interpolation. Therefore, it is possible to define one template that reflects changing level differences and slopes within the template along the length of the project.

Horizontal alignments are set up in CivilSoft's Highway Design Program and cannot be retrieved from alignments set up in COGO. Manual realignment is required for each new horizontal alignment desired. CivilSoft allows for specification of "pavement" thickness. Templates assigned to alignments can be transitioned between stations by specifying different widths for various elements of the template, thus allowing changing road widths throughout the project. CivilSoft also allows vertical ditch alignments along a road to be specified independently of the road centerline.

In CEAL, horizontal alignments are specified through COGO. Alignments, specified as centerlines in COGO, can be placed in any arrangement within the boundaries of the original surface data. A template can be assigned to a horizontal alignment through definition of a cross sectional model. The same template can be assigned as an offset to the centerline, which is useful in dual highway design. For transitioning, the maximum variations of the template to be used along the same horizontal alignment must be specified and stored as separate templates. CEAL software requires the user to specify the stations at which these templates are located and then it transitions between stations. CEAL also allows vertical transitioning of elevations and slopes within the template along the length of the project.

It should be noted here that CLM/Systems reviewed the test results for CEAL and raised strong objections to the findings. In the case of the multiple alignments function, CLM/Systems stated that there was a "misunderstanding of how templates work in CEAL, leading to invalid conclusions."

Multiple Profiles

Wescom will create any natural surface profile defined by a traverse in COGO. It permits up to six template edge profiles (e.g., centerline of road, top of curb, left and right ditch) to be plotted at once in addition to the natural surface profile. Elevations, stationing, and gradients can be annotated on the plot.

CivilSoft cannot create a natural surface profile without manual input of cross sectional data. Profiles of road centerline and left and right ditches can be plotted. Profile stationing annotation is based on 1-in. increments and the user-defined scale. This condition causes some irregularity in annotation.

CEAL can plot a natural surface profile and can provide natural surface elevations along a centerline when the user specifies natural surface cross sections of width 0. Multiple profiles are possible by transitioning different slopes and edge elevations between stations. CEAL, however, cannot provide plots of profiles other than the designed centerline or natural surface profiles.

Multiple Surfaces

Wescom provides multiple surfaces by creating three-dimensional meshes of design and natural surfaces. Design meshes can be created by adding design data to a natural surface mesh. Linear elements such as roads and ditches can be added through specification of template and alignments. Cross sectional templates are input into a mesh as strings of points along elements of the template. The template cannot have strings directly vertical from each other (e.g., a road curb face cannot be defined as an exactly perpendicular surface). However, the string can be given a minor offset and be accepted by the program. Engineered surfaces can be added by defining new points and geometric areas, or by specifying new elevations to COGO-defined geometric areas and providing a desired slope back to natural surface. Geometric areas can be designed flat or sloped, but cannot be twisted. Slopes from the designed engineered surface can be specified by percentage slope back to the natural surface or can be given a "boundary" at which to meet the natural surface, therefore creating uneven slopes around the surface. Wescom provides for design elements such as retaining walls and allows users to specify new spot elevations. Design meshes are stored by Wescom for later volume comparisons. Any mesh can be compared with any other mesh or with a chosen elevation.

CivilSoft has no provision for multiple surfaces.

CEAL allows the user to define separate contour and triangulated (tin) models which are stored as separate files. It is possible to design surfaces by creating new contour models using design contours. Volumes of contour models can be computed and compared with volumes of other contour models. It should be noted that an contours must first be designed by the user. CEAL does not allow surfaces or side slopes from surfaces to be input. CLM/Systems refuted this finding and stated, "Conclusions are false."

Automatic Sectioning

Wescom can provide cross sections along any traverse line defined in COGO at any interval specified by the user. Cross sections are based on mesh data interpolated between input data points. Input data does not have to be linearly offset from a traverse. Cross sections of natural surface can be plotted simultaneously with design surface cross sections.

CivilSoft can use information from its COGO-PC PLUS program in HDP to generate natural surface cross sections from input data points, provided the data points approach linearity perpendicular to the centerline. Otherwise, cross sections will be calculated only if the user directly inputs natural surface cross section elevations.

CEAL can provide cross sections along any centerline traverse defined in COGO and at any interval specified by the user. Cross sections are computed by using intersection elevations of contours in the contour model, or triangles in the triangulation model, and perpendicular widths of cross sections along stations of the centerline. If the contour interval is too large or contours run perpendicular to the centerline, few or no crossings will occur, causing a loss in accuracy. Use of the tin model is more accurate.

Templates on Existing Ground

Wescom can provide natural surface profiles and station elevations of any design centerline. It is therefore possible to design a vertical alignment using existing centerline elevations, thus allowing design templates to be placed over existing surfaces.

CivilSoft does not provide existing surface profiles. Therefore, unless field elevations along proposed design centerlines have been provided, it is not possible to place design templates over existing ground.

CEAL can provide natural surface profiles of any design centerline. Station elevations along a centerline can be obtained by computing natural surface sections along the centerline and specifying a width of 0. It is therefore possible to design a vertical alignment using existing centerline elevations, thus allowing design templates to be placed over existing surfaces.

Catch Points

Wescom, CivilSoft, and CEAL will prompt an error message if the daylight points (template slope to natural surface intersection) are not within the limits of the natural surface data or cross sectional width specified by the user. Wescom allows the user to extend the limits of the mesh. CivilSoft allows an increase of 100 ft outside of the farthest data point. CEAL permits the user to extend this length of contour chains in the contour model.

Surface Area Calculations

Wescom has no provision for surface area calculations at this time. CivilSoft can calculate "seeding" areas between cross sections. The user must differentiate between paved and seeded areas. CivilSoft then uses the lengths of the areas designated as "seeded" at successive sections, averages them, and multiplies by the distance between stations.

CEAL has no provision for surface area calculations at this time, although CLM/Systems said this "statement is false." No information is available to show how this function is activated if it is, in fact, possible.

Staking

When the user wants staking information along curved horizontal alignments, Wescom will provide the following information: stationing along alignment, deflection angle to each station around the curve, chord distances between stations, bearings between stations, angle at each station, and coordinates of all stations on the traverse.

CivilSoft allows the user to specify stationing along an alignment and calculate chord distances and bearings between stations. In addition, Civilsoft provides a single command that allows a horizontal curve to be defined from any point, providing distance and bearing information from that set point to the stationing points on or offset from the alignment centerline.

CEAL provides the following information along curved horizontal alignments: stationing along alignment, deflection angle to each station around the curve, arc length, radius, and tangent. A distinction is made between highway and subdivision curves. Subdivision staking provides arc length and chord bearing, whereas highway staking provides deflection angles, arc lengths, radius, and tangents.

All three software packages can provide "slope staking" or catch points. These points where no cut or fill is required can be printed in table form and plotted in all packages.

Volumes

Wescom can calculate volume either between stations along an alignment or between meshes. Volume between cross sections can be calculated in Wescom using either a modified average end area or a "prismoidal" method. Using the average end area method, Wescom divides the cross section into areas that are in cut and areas that are filled, providing volumes for each. The differences between cut and fill volumes are calculated after they have been multiplied by the cut and fill factors, respectively. The prismoidal method calculates volume using length x [(A1+SQRT(A1+A2)+A2)/3] rather than the length x [(A1+A2)/2] used in the average end area method. The prismoidal method cannot be used when the horizontal alignment contains curves. When calculating volumes based on meshes, the user can input a natural surface mesh, a design mesh, a "lower level," and a "higher level." If both lower level and higher level are left blank, Wescom will compute the volumes between the two meshes within any horizontal window specified. If only the lower level is specified, the volume is computed between the natural surface mesh and the lower level and within any horizontal window specified. If both lower level and higher level are specified, the volume is computed which is both between the two meshes and the two levels, and within any horizontal windoW specified. All volumes are multiplied by cut and fill factors specified by the user.

CivilSoft calculates volumes between cross sections along a horizontal alignment. Volumes can be calculated using either the average end area or the prismatic method. Values are divided into cut and fill volumes and are based on the cut and fill factors specified by the user. Equations for average end area and prismatic calculations are the same as those given above.

CEAL calculates volumes using the average end area method. Areas between stations along an alignment are divided into cut and fill sections and multiplied by the user-supplied cut and fill factors. CEAL can also calculate volumes based on contour models. Areas within a closed contour are calculated and the average end area method is used vertically to compute the volumes between successive contours for all pairs of contours. This method works well only when contours are regular and in consecutive order. The user can specify the minimum and maximum contour elevations to compute as well as a

reference contour that acts as a horizontal plane above which volumes are considered to be fill, and below which volumes are considered to be cut. A tabulation is printed, providing the area of each contour, incremental volumes, and cumulative volumes. Cut and fill factors are not included in volume calculations using this method.

Mass Balance

Wescom provides a grid volume diagram (see Appendix C) from the mesh information provided: natural surface mesh, design surface mesh, higher level, and lower level. The diagram is based on northing and easting intervals provided by the user and shows the cut and fill volumes within each interval. Wescom can generate natural/design cross sections that can be used as a reference to providing a balanced design. No mass balance diagrams along horizontally designed elements are calculated.

CivilSoft provides a mass haul "balance" diagram along an alignment. This diagram is a graphed summation of cut and fill volumes along an alignment. If desired, CivilSoft will plot the ideal offset at each station to obtain a minimum of earthwork. CivilSoft also can generate natural/design cross sections that can be used as a reference to providing a balanced design.

CEAL's current software version has no provision for plotting a mass haul or mass balance diagram. (Note: according to CEAL's literature, version 5.13 will be able to create mass haul and earthwork analysis diagrams.) CEAL can generate natural/design cross sections that can be referenced when providing a balanced design.

Summary of Findings

When benchmark testing was completed, the results were analyzed for the three packages and the features were rated. Figure 1 shows the relative software ratings.

All three packages perform similarly in their ability to generate a site design using COGO. They also produce similar results when creating contour maps from input data. CEAL and Wescom share an advantage over CivilSoft when calculating cross sections and profiles from natural surfaces. CivilSoft cannot create cross sections from data without manual entry of the natural cross section elevations. This proves to be a distinct disadvantage for calculating average end area volumes along linear elements.

Both CEAL and CivilSoft have processing speed advantages over Wescom's mesh files when creating triangulation models. Wescom, however, allows the mesh file to be used as a basis for incorporating engineered and linear elements. This process allows easy volume calculations between separate layers. CEAL allows the user to create "models" that can be stored, altered, and used as a basis for cross sections and profiles. However, it is not possible to incorporate engineered and linear elements into a model, such as a contour or triangulation model, without manually calculating slopes and drawing the design contours.

CivilSoft lacks the ability to create design surfaces, placing the emphasis on linear design elements. Engineered surfaces must be designed linearly, which proves difficult or impossible for irregularly shaped surfaces. CEAL and CivilSoft created triangulation models much faster than Wescom could generate a mesh file.

Other general areas in which software packages were either better than average or deficient compared with the other packages include the following:

Installation: CEAL was a bit more complex to install than the other packages because of its requirement for allocating extended memory and the corresponding changes to the autoexec.bat and config.sys files.

Integration: the division of CivilSoft's packages was a disadvantage. Separate drivers were required for plotting from different packages, and one package even required a differently configured plotting cable. (Note: this situation has reportedly been solved in later releases.) In addition, the different methods in which batch files were created was confusing when switching from package to package.

Input: no package had a decided advantage over others in the type of input it accepted. Wescom proved to be somewhat more efficient in accepting x, y, z random data in that it allowed user-defined fields, whereas the other packages required information to be in exact fields.

	WESCOM	CEAL	CIVILSOFT
MULTIPLE ALIGNMENTS	3	3	2
MULTIPLE PROFILES	3	3	2
MULTIPLE SURFACES	3	2	1
AUTOMATIC SECTIONING	3	3	1
TEMPLATES ON EXISTING GROUND	3	3	1
CATCH POINTS	3	3	3
SURFACE AREA (SEEDING) CALCULATIONS	1	1	3
STAKING	3	3	3
VOLUMES BY AVG. END AREA	3	3	3
VOLUMES BETWEEN SURFACES	3	2	1
MASS BALANCE/HAUL	3	1	3

Figure 1. Software rated by capability. A "3" indicates that the software can perform the task, "2" indicates that the software can perform the task but with some difficulty or manipulation by the user, and "1" indicates that the software cannot perform the task at this time.

Output: all packages met the expectation that data be transferable through DXF output. CEAL also was able to transfer plot files to IGES format. Wescom did not require hardware locks, unlike the other two software packages. In addition, Wescom was the only package that did not require a separately configured cable to plot both Wescom and CADD plots. CEAL not only required a different cable configuration, but a different plotter configuration as well, making it time-consuming to switch from CEAL plots to AutoCad plots and vice-versa.

Processing speed: Wescom took a maximum of 1 hr to create large mesh files from user input data compared with the other packages in creating triangulation models, which took only a few minutes. However, CivilSoft's triangulation network was solely for the purpose of creating contours. CEAL's triangulation model (stored as a text file) had to be converted to other types of models such as a contour, section, or end area model before other calculations could be performed; this requirement still represented a significant time savings.

Batch procedures: Wescom was the only package that required an outside text editor to create batch files. Although batch files could be created using the DOS edlin program, it was found to be clumsy. USACERL tested Wescom using Sidekick's Notepad. The CivilSoft batching procedures were confusing to learn because of the variation in packages.

Training/support: Wescom had an advantage over the other packages because its regional distribution system allowed a local agent to present training over random, rather than consecutive days. This arrangement allowed training to proceed at the users' pace and gave users the opportunity to prepare questions prior to training sessions. Wescom also provided sample batch files with comment lines describing each command, which was useful for future modeling of projects. Telephone support was provided equally by all software companies, although CivilSoft's normal policy is to charge a fee for each call or each year of telephone support.

Reference manuals: it was sometimes difficult to locate information in CEAL's reference manuals. Commands were listed singly and guidance for constructing batch files and ordering commands was difficult to follow from a user standpoint. Plotting commands were listed in a document separate from the manual for commands used to create a product (i.e., the user must first find a reference for creating a design cross section in one manual and then look up plotting cross sections in another manual).

The results of USACERL's benchmark testing suggest that, at present, Wescom offers the software best suited to USACE's needs in civil engineering. This package can interface with the Districts' existing PCs and CADD software, and most nearly fulfills the criteria established for this study. This finding in no way implies that the other two programs are inadequate; indeed, both CEAL and CivilSoft are excellent products. However, in serving USACE's objectives for automated site design, the Wescom software appears to be the best suited of the three products tested.

5 CONCLUSIONS AND RECOMMENDATIONS

USACERL has assessed the need among USACE Districts and Divisions for computer programs to automate civil/site engineering. A questionnaire administered to USACE civil engineers indicated that there is high interest and an immediate need for such programs to improve design efficiency.

Feedback from the questionnaire was used to establish criteria for software that could potentially meet USACE's needs. One of the most important requirements was that programs be operable on the IBM or compatible PC due to the large number of these machines already in service at the Districts and Divisions. In addition, design for MILCON projects often has requirements unique to the building industry and, therefore, it was necessary to define the criteria making software most conducive to USACE work. These criteria were refined and validated through the Site Design Steering Committee, which included representatives from USACE headquarters, Districts, and Divisions.

Based on the criteria established, USACERL surveyed the software industry for promising candidates. This assessment produced three software packages that could potentially meet the criteria—Wescom, CivilSoft, and CEAL. It was determined that these products would be bench-tested at USACERL.

The benchmark testing involved two parts: the first was related to data input and transfer among systems and the second consisted of a test problem. Software performance in each area was documented carefully; the results were then compared and the products assigned a rating (Figure 1). The findings showed that, at present, Wescom offers the software most appropriate for USACE's construction program. This conclusion was based solely on the test softwares' performance in the stated criteria and is true only for the product versions available as of March 1988.

Based on these results, it is recommended that USACE elements considering the purchase of a civil engineering site design program select the Wescom package. Among the products evaluated, this software most nearly meets USACE's needs as established by the test criteria.

It is important to note that the computer software industry is in a state of constant change, creating difficulties for researchers in testing and recommending software. By allowing ample time to complete a qualified test of independently manufactured software, the researcher also bears the risk that the software being tested will become outdated or obsolete. It is USACERL's position that this test of civil engineering site development software has revealed the best software program for USACE's needs at the exact time of the test. Recommending one manufacturer's package at this time does not guarantee this product will remain at the forefront of the industry.

In the next phase of this project, the Wescom software will be field-tested at the Chicago and Sacramento Districts. Each District will use the software in an actual construction project and report on its performance. Meanwhile, USACERL will continue to identify and assess civil site software programs so as to be aware of changes in the industry that could potentially benefit USACE.

In addition, USACERL will expand its research to address related issues: geotechnical and utilities analysis interfaces, landscape design and visual simulation, and data capture automation.

APPENDIX A:

ENGINEERING DESIGN QUESTIONNAIRE*

This questionnaire is designed to assist USACERL in evaluating the needs and desires of those District offices involved in military construction. Specifically, these questions deal with engineering site design programs for the microcomputer. Please mail the completed questionnaire in the enclosed envelope within 1 week of receipt.

1. What type(s) of microcomputers do you have available for engineering design purposes? Indicate the number of each in the blank following:

IBM AT	87	Zenith	90	Compaq	3
IBM XT	33	TI	0	HP	4
Other IBM	0	WANG	0	Apollo	10
Compatible	104			Altos	2

2. What type(s) of microcomputers do you anticipate procuring in the next 12 months for engineering design purposes? Indicate the number of each in the blank following:

IBM AT	84	Zenith	115	Compaq	9
IBM XT	11	TI	0	HP	1
Other IBM	0	WANG	0	Apollo	5
Compatible	22			Kaypro	1

3. Which of these peripherals are you currently using? Indicate the number of each in the blank following:

Plotter	53	Mouse	74
Tablet	47	Digitizer	42

4. If you are using computer programs for any of the following functions, please list by name of package/vendor.

Function:	Surveying	Contouring	Roadwork
	Layout	Earthwork	Structures
	Site Planning	Utilities	Other

5. Please briefly explain the outstanding features and/or shortcomings of these, programs.

6. Are any of the programs used in conjunction with the CAD system currently used? If so, which ones?

7. What drafting program(s) is your branch using now (e.g., AutoCAD, Intergraph, CadPlan)? Please list.

*For questions with numerical responses, the totals are listed. Responses to the other questions are summarized at the end of the questionnaire.

8. Are the above drafting programs being used:

___ Casually? ___________ (system)
___ Regularly?___________ (system)
___ Intensively?__________ (system)

9. Please briefly explain the outstanding features and/or shortcomings of these drafting programs.

10. For which of these areas would you like to obtain programs?

Surveying	25	Contouring	30	Road layouts	28
Earthwork	2	Structures	14	Site planning	28
Utilities	3	Other	16		

11. Indicate how much money your branch is willing to spend to obtain a comprehensive site adaptation/design system.

$1000 - $6000	9	$6000 - $10,000	7
$10,000 - $25,000	5	$25,000 - $50,000	2
More than $50,000	4	Satisfied - $0.00	3

12. Indicate the size of your in-house design effort.

_1_ Small (basically review contracted design efforts)
_22_ Medium (perform both review and design functions)
_12_ Large (extensive in-house design program)

Comments? ______________________________

13. Would your branch be willing to send a representative to USACERL in the near future to participate in a task group studying computer applications for engineering design?

_24_ YES _13_ NO

14. Is your design branch interested in helping evaluate computer programs that may benefit your office later?

_31_ YES _5_ NO

15. Please furnish your name, title, and telephone number (commercial or FTS).

16. Please indicate name, address, and telephone number (commercial or FTS) of person to contact for further information.

Thank you for your time and effort In providing this information.

Please return the questionnaire in the stamped, self-addressed envelope to:

U.S. Army Construction Engineering Research Laboratory
P.O. Box 4005
Champaign, IL 61820-1305
Attention: FS/B. Meier

QUESTIONNAIRE RESPONSES ON SOFTWARE

Huntsville Division

Huntsville Division
Huntsville, AL
POC: Ronald E. Brown
COMM 205-895-5240

Currently using:*	Intergraph: earthwork, DTM, contouring (very powerful interactive software, used intensively)
Would like to obtain:	Utilities, contouring, road layouts, site planning, storm drainage
Willing to spend:	$10,000 to $25,000
Size of design effort:	Medium

Lower Mississippi Valley Division

Vicksburg District
Vicksburg, MS
POC: John Hood
COMM 601-634-7195

Currently using:	Structure-CFRAME, CSTR-WES, SurveyingGCOGO, Utilities-DAPPER, Intergraph (used intensively for general civil applications)
Would like to obtain:	The Corps-wide CADD buy should include all items listed. If this is the case, we may not need any.
Willing to spend:	(blank)
Size of design effort:	Large

Memphis District
Memphis, TN
POC: Allen Bodron
COMM (901) 521-3921

Currently using:	Corps-developed programs; No CADD system

*Note: the lists of systems used and desired were copied from the questionnaire, which has resulted in some inconsistency in system names and spelling.

Would like to obtain:	Earthwork, structures, road layouts, site planning
Willing to spend:	More than $50,000
Size of design effort:	Medium

New Orleans District
New Orleans, LA
POC: Robert J. Grubb
COMM (504) 862-2678

Currently using:	WES Corps Library programs (require too much memory, do not fully support graphics on micros), Computevision (main CADD system used regularly, good)
Would like to obtain:	Surveying, earthwork, structures, road layouts, site planning
Willing to spend:	$1000 to $6000
Size of design effort:	Large

St. Louis District
St. Louis, MO
POC: Michael Rector
COMM (314) 263-5677

Currently using:	COGO-PC/Civilsoft, EARTH COMP SYSTEMSearthwork package, Corps of Engineers CASE/Corps Library, DTM, and others, Architectural Production Package-DMS, AutoCAD (used casually, limited to small files), CCADD (used intensively, excellent)
Would like to obtain:	Surveying, earthwork, utilities, contouring, structures, road layouts, site planning
Willing to spend:	$6000 to $10,000 (software only)
Size of design effort:	Large

Missouri River Division

Kansas City District
Kansas City, MO
POC: Tim Kuhlman
COMM (816) 374-5408

Currently using:	Structures-CFRAME, Structures --C--CADD, software for all general civil uses (in conjunction with CAD), C-CADD (used regularly, can be hard to operate), Intergraph (used intensively)
Would like to obtain:	Surveying, earthwork, contouring, structures, road layouts, site planning, Quantity Take-off-CADD
Willing to spend:	$6000 to $10,000
Size of design effort:	Medium

Omaha District
Omaha, NE
POC: Gary Lien
COMM (402) 221-4543

Currently using:	MacAuto-Roads, road layout, Wadiso-water network, utilities, AutoCad (used casually), Intergraph (used intensively)
Would like to obtain:	DTM (C.L. Miller or Arose)
Willing to spend:	$6000 to $10,000
Size of design effort:	Medium (design program expected to increase in FY87)

North Atlantic Division

Baltimore District
Baltimore, MD
POC: Len Martin
COMM (212) 264-4187

Currently using:	Wild Heergbrugg: surveying, earthwork, plotting (road layout), PacSoft: DTM (difficult to operate), no CADD system as yet.
Would like to obtain:	Surveying, earthwork, utilities, contouring, structures, road layouts, site planning, architecture, mechanical, electrical
Willing to spend:	$10,000 to $25,000
Size of design effort:	Medium

New York District
New York City, NY
POC: Andrew Knapp
COMM (212) 264-9217

Currently using:	AutoCAD (used regularly)
Would like to obtain:	Surveying, earthwork, utilities, contouring, structures, road layouts, site planning
Willing to spend:	$0.00
Size of design effort:	Medium

Norfolk District
Norfolk, VA
POC: Gerald Coffey
COMM (804) 441-3613

Currently using:	Kentucky program, ALLWET, Wadiso, CFRAME, COGO, AutoCad (need AROSE or AutoCOGO to drive AutoCad), CCAD (used casually), CADPack
Would like to obtain:	Surveying, earthwork, utilities, contouring, structures, road layouts, site planning.
Willing to spend:	$10,000 to $25,000
Size of design effort:	Medium

North Central Division

Chicago District
Chicago, IL
POC: Jeff Frauenfelder
COMM (312) 353-6502

Currently using:	AutoCad, in-house application programs written in AutoCad command language, AutoLISP, and BASIC
Would like to obtain:	Surveying, earthwork, utilities, contouring, road layouts, site planning, DTM
Willing to spend:	$6,000 to $10,000
Size of design effort:	Medium

Detroit District
Detroit, MI
POC: William Lawhead
COMM (313) 226-6780

Currently using:	Corps library, structures, earthwork, COGO, surveying, CDC-ICEMS (used casually, extensive menus, high system use charges)
Would like to obtain:	Earthwork, contouring, structures, road layouts, site planning, soils
Willing to spend:	\$1000 to \$6000
Size of design effort:	Medium

Rock Island District
Rock Island, IL
POC: John A. Kincaid
COMM (309) 788-6361

Currently using:	WES, adapted Corps library program; in the process of procuring AutoCad and Microstation II CAD
Would like to obtain:	Earthwork, structures, site planning
Willing to spend:	(blank)
Size of design effort:	Medium

North Pacific Division

Alaska District
Anchorage, AK
POC: Thomas Lubeck
COMM (503) 221-2801

Currently using:	WES, water distribution system analysis, AutoCAD (recently purchased by Architecture Section)
Would like to obtain:	Earthwork, utilities, contouring, road layouts, site planning
Willing to spend:	\$10,000 to \$25,000
Size of design effort:	Medium

Seattle District
Seattle, WA
POC: Christine M. Engler
COMM (206) 764-3793

Currently using:	Halo and RDS (not currently tied into CADD system), DTM/DTMW-Intergraph (VAX host, clumsy and slow, being replaced by Intergraph), COGO-Intergraph (VAX host)
Would like to obtain:	Surveying, earthwork, utilities, contouring, structures, road layouts, site planning, any of the above linked to CADD
Willing to spend:	Depends on the endproduct
Size of design effort:	Medium

Walla Walla District
Walla, WA
POC: Mary Brammer,
FTS 434-6568
COMM (509) 522-6568

Currently using:	GCOGO: Waterways Exp. Station, CivilSoft (not in use yet, investigating), EASI Software, concrete design, steel design, Research Eng. Inc.: STAAD III, MTI Software, foundation design, WES Corps Library, Intergraph (used intensively, needs better software support), C-CADD (just beginning but outperformed by Bentley), Bentley (just beginning)
Would like to obtain:	Surveying, earthwork, road layouts
Willing to spend:	$10,000 to $25,000
Size of design effort:	Medium

Ohio River Division

Huntington District
Huntington, WV
POC: Kennard M. Waddell
COMM (513) 684-3002

Currently using:	Symphony: earthwork; WES: structures; CGOGO: surveying (shortcoming—control of output); CDCControl Data Corp. (used intensively, very flexible and adaptable; however, needs to be faster)

Would like to obtain:	Surveying, earthwork, utilities, contouring, structures, road layouts, site planning, perfect management
Willing to spend:	More than $50,000
Size of design effort:	Large

Louisville District
Louisville, KY
POC: Bill Steinbock
COMM (502) 582-5601

Currently using:	Site-(digitizing) Micro Station II (Bentley System) (creates 100 percent compatible design files for Intergraph—good), GCOGO (WESS), road layout and surveying, Allen Engineering Technologies, Structural, CFRAME (WES) (poor graphics)
Would like to obtain:	Surveying, earthwork, contouring, road layouts, site planning
Willing to spend:	$1000 to $6000
Size of design effort:	Large (both civil and military design done in-house)

Nashville District
Nashville, TN
POC: Herman Gray
COMM (615) 736-5650

Currently using:	Corps Library Structural Programs (poor graphics), Intergraph (used regularly, versatility good, database poor), CivilSoft: COGO, contouring, and earthwork
Would like to obtain:	Surveying, earthwork, contouring, structures, site planning
Willing to spend:	$1000 to $6000
Size of design effort:	Medium

Pittsburg District
Pittsburg, PA
POC: John Frazier,
COMM (412) 644-4003

Currently using:	Corps programs: structural (insufficient user interfacing, poor manual quality), DOGS-Design Oriented Graphics System (interfacing capability limited)
Would like to obtain:	Surveying, earthwork, contouring, structures, road layouts, site planning, electrical, mechanical
Willing to spend:	More than $50,000
Size of design effort:	Medium

South Atlantic Division

Charleston District
Charleston, SC
POC: Hal Smith
FTS 677-4318

Currently using:	Structural programs, no CADD system
Would like to obtain:	Surveying, earthwork, utilities, contouring, road layouts, site planning
Willing to spend:	$1000 to $6000
Size of design effort:	Large

Jacksonville District
Jacksonville, FL
POC: William K. Wigner, Jr.
COMM (404) 331-2799

Currently using:	WES, structural analysis and surveying programs (easy to use), other design programs written in-house, CADKey (used casually on Zenith PC, not happy with it)
Would like to obtain:	Earthwork, utilities, contouring, road layouts
Willing to spend:	$6000 to $10,000
Size of design effort:	Medium (only a small amount of military work being done)

Mobile District
Mobile, AL
POC: C.W. King
COMM (205) 690-2635

Currently using:	WES: pavement design; DataTech: road geometry, storm sewer design, earthwork, roadway geometry; Intergraph (used regularly, user-friendly, productive)
Would like to obtain:	Surveying, earthwork, contouring
Willing to spend:	$6000 to $10,000
Size of design effort:	Medium

Savannah District
Savannah, GA
POC: Joe Rogers
COMM (912) 944-5688

Currently using:	CivilSoft: earthwork, storm (program not being used at present time); Intergraph (used casually)
Would like to obtain:	Surveying, earthwork, utilities, contouring, road layouts, site planning
Willing to spend:	$25,000 to $50,000
Size of design effort:	Medium

Wilmington District
Wilmington, NC
POC: David Page
FTS 671-4057

Currently using:	In process of purchasing CEAL by C.L. Miller Inc., AutoCAD (used casually, plan to use with CEAL)
Would like to obtain:	Surveying, earthwork, utilities, contouring, road layouts
Willing to spend:	(blank)
Size of design effort:	Medium

South Pacific Division

South Pacific Division
San Francisco, CA
POC: Ken Kuhn
COMM (919) 343-0929

Currently using:	CivilSoft, AutoCad (used regularly, inexpensive, easy to learn)
Would like to obtain:	Surveying, earthwork, utilities, contouring, structures, road layouts, site planning
Willing to spend:	$0.00 (satisfied)
Size of design effort:	Small

Los Angeles District
Los Angeles, CA
POC: Cliff Ford
FTS 798-5530

Currently using:	CivilSoft (recently purchased), AutoCad (used regularly)
Would like to obtain:	Surveying, earthwork, contouring, road layouts, site planning
Willing to spend:	$25,000 to $50,000
Size of design effort:	Large

Sacramento District
Sacramento, CA
POC: Dan Reynolds
COMM (213) 894-5300

Currently using:	Kypipe: Water distribution system, Land; CADD: landscaping, AutoCOGO, Geodimeter Surveying Software: field survey data collection, MTEN3: national geodetic survey, CAEADS site: from USACERL/University of Michigan, currently looking at more packages including, AROSE, CivilSoft, DTM by PacSoft and others. AutoCAD (used intensively), Genericad (used casually), CadKey (used casually), MegaCAD (used regularly to do perspectives)

Would like to obtain: Surveying, earthwork, utilities, contouring, structures, road layouts, site planning

Willing to spend: $10,000 to $25,000

Size of design effort: Large

Southwestern Division

Albuquerque District
Albuquerque, NM
POC: Peter Doles
COMM (214) 767-2614

Currently using: CivilSoft: COGO PC-Plus, Contour, Earthwork 2 (programs require experienced user and are cumbersome, information is not converted to AutoCAD easily; would not recommend), AutoCAD (used regularly, very satisfied)

Would like to obtain: Surveying, earthwork, utilities, contouring, site planning

Willing to spend: $1000 to $6000

Size of design effort: Medium

Fort Worth District
Fort Worth, TX
POC: Cecil Adcock
COMM (817) 344-2312

Currently using: Just recently installed PCs

Would like to obtain: Surveying, earthwork, utilities, contouring, road layouts, site planning

Willing to spend: (blank)

Size of design effort: Large

Galveston District
Galveston, TX
POC: Robert Phillips
COMM (409) 766-6834

Currently using: (blank)

Would like to obtain:	Electrical-lighting, conductor sizing, short-circuit calculations
Willing to spend:	(blank)
Size of design effort:	Virtually 100 percent civil works, no military design as this time

Little Rock District
Little Rock, AR
POC: Joe L. Pearce
COMM (501) 378-5668

Currently using:	LEITZ COGO PLUS--LEITZ Co.: surveying; LAND IMPROVE—A.B. Consulting Co., Inc,: road layout; Intergraph (regular use)
Would like to obtain:	Surveying, earthwork, utilities, contouring, road layouts, site planning, drafting, plotting graphs
Willing to spend:	$1000 to $6000
Size of design effort:	Medium

Tulsa District
Tulsa, OK
POC: Kent Meyers
COMM (918) 581-7243

Currently using:	MOSS/Autotrol: earthwork, contouring, site planning, road layout (interactive online editing, 3-D Modeling, however some British terminology used, no online help, slow on Autotrol 5O's in conjunction with CADD), AutoCad (used casually, speed, memory, storage), S5K/Autotrol (used intensively, lack of good translator)
Would like to obtain:	Surveying, earthwork, utilities, contouring, structures, road layouts, site planning , 3D modeling
Willing to spend:	More than $50,000
Size of design effort:	Large

Other Responses

Listed below are offices willing to send a representative to USACERL to participate in a task group and interested in helping evaluate computer programs.

Huntsville Division:

CEHND, Huntsville Division, AL

Lower Mississippi Valley Division:

CELMK, Vicksburg District, MS

CELMM, Memphis District, TN

CELMN, New Orleans District, LA

CELMS, St. Louis District, MO

North Atlantic Division:

CENAB, Baltimore District, MD

North Central Division:

CENCC, Chicago District, IL

CENCE, Detroit District, MI

CENCR, Rock Island District, IL

North Pacific Division:

CENPA, Alaska District, AK

CENPS, Seattle District, WA

CENPW, Walla Walla District, WA

Ohio River Division:

CEORH, Huntington District, WV

CEORP, Pittsburg District, PA

South Atlantic Division:

CESAC, Charleston District, SC

CESAM, Mobile District, AL

CESAS, Savannah District, GA

South Pacific Division:

CESPD, South Pacific Division,

CA CESPL, Los Angeles District,

CA CESPK, Sacramento District, CA

Southwestern Division:

CESWA, Albuquerque District, NM

CESWF, Fort Worth District, TX

CESWL, Little Rock District, AR

CESWT, Tulsa District, OK

Offices saying they were unable to send a representative to USACERL to participate in a task group but interested in helping evaluate computer programs were:

North Atlantic Division:

CENAN, New York District, NY

CENAO, Norfolk District, VA

CENAP, Philadelphia District, PA

Ohio River Division

CEORL, Louisville District, KY

CEORN, Nashville District, TN

South Atlantic Division

CESAW, Wilmington District, NC

APPENDIX B:

TEST PLAN

The software testing was divided into two phases. Phase I involved benchmark testing (Chapter 4) and had two subparts—(1) testing the software's input capabilities and other features and (2) assessing its performance in a problem. Phase II will involve the field test. Questions asked by the group in the Phase I evaluation were:

1. What are we testing for in Phase I?
   a. Input:
      - Survey Data
      - Digitized Data
   b. Design Analyses
   c. Design Solution:
      - Volumes
      - Quantities
   d. Output:
      - Hardcopy
      - Screen
      - To CADD

2. What forms of input will the software accept?

3. Is there flexibility in editing input?

4. What output will the software produce?
   a. Types
   b. Destinations:
      - CADD
      - Intergraph

5. How integrated is the package?

6. What is the installation procedure for the package?

7. What are the hardware requirements?

8. What is the capability of the software to perform the following functions:
   a. Multiple alignment
   b. Multiple profiles
   c. Multiple surfaces
   d. Templates on existing ground
   e. Multiple templates—how many
   f. Specification of what if's for catch points
   g. Transition between templates
   h. Curve correction (automatic)
   i. Sectioning (automatic)

j. Staking
k. Plan profile
l. Mass balance:
  - Side to side
  - Along alignment
m. Volumes:
  - Between DTM surfaces
  - Average end area
n. Surface area calculations
o. Slice a section through the DTM—does the utility line show up?

The evaluation procedure in Phase II included:

1. Describe how long the procedure and the task took to complete.
2. Describe the data required.
3. Document all telephone calls to the vendor (support).
4. Describe the accuracy of the software.
5. Describe the limits of the software.
6. Describe the procedure that was performed.
7. Describe the speed for the processing.
8. Describe the batch processing procedure.
9. Describe the training support offered.
10. Describe the ability to integrate existing utility programs.
11. Describe the time taken for researching documents to solve problems.
12. Describe the contents of the package, the cost of the pieces, and the site licensing agreement.
13. Describe the marketing scheme.
14. Describe the hardware requirements.

The evaluation procedure was intended to:

1. Do as much as necessary to test the software feature, then stop.
2. Use one model to test input data.
3. Not be constrained by the real situation in the design problem--manipulate to test the software procedure.
4. Compare the performance of each software package against the criteria and against each other.

Design problems submitted by the task group include:

1. Site designs—
    - St. Louis District
    - Seattle District
    - Sacramento District.

2. Input test material—
    - Field Book - St. Paul District
    - Plane Table Sheet - Ft. Worth District
    - Digital Terrain Data - Sacramento District

Phase II—validating the software in a production scenario—is to consist of the following:

USACERL Requirements

1. Start making contacts to trigger District interest in Phase II now.
2. Develop a technology transfer plan.
3. Determine how the training will be accomplished.
4. Develop a standard report format for the test Districts' feedback. This format should consist of standard questions with fill-in answers.
5. Support the purchase cost.
6. Develop a lessons-learned report.
7. Support the needs of the field operating agency (FOA).
8. Maintain ongoing sharing of lessons learned.
9. Integrate existing utility programs.
10. Integrate geotechnical requirements.
11. Integrate survey requirements.

Test District

1. Two districts should test each software product.
2. The districts will be volunteers.
3. They will commit resources:
   - Time
   - Money
   - Manpower
4. They will use the software in the design analyses and design solution phases of an actual project.
5. The validation would not jeopardize production milestones.

Districts that have site development application software are:

Intergraph	CivilSoft	CEAL	WESCOM
St. Louis, MO	Wilmington, DE	Wilmington, DE	St. Paul, MN

APPENDIX C:

WESCOM SOFTWARE TEST

Tests on the Wescom product involved software updates received prior to March 20, 1988.

Part I

Phase I of the software test was divided into two parts, the first of which involved inputting electronic data from a floppy disk into the software package, creating a contour map, and comparing it with the existing contour map provided with the data. X, Y, Z data were provided, along with point numbers and a point code, all in a fixed-field format.

Input

The Wescom "Carin" routine allows the user to define in which fields data are located without having to change the data. Some data points from the original data were not desired, these points included tree locations, manholes, and other object locations. Because a point code was provided with the data, it was possible to screen the field containing the point codes and omit undesired codes. With this process, it is also possible to obtain information for ranges of data by specifying the range in any field that data will be acceptable.

Contours

Wescom generates contours by first creating a digital terrain model or "mesh" file based on intervals specified by the user. The interval is determined by the mesh distribution and the desired use for the model. This file, interpolated from X, Y, and Z data, can be altered when the user adds "ridge lines," and changes rounding, smoothness, and ridge honoring factors. Ridge lines allow the user to more closely represent the valleys and ridges of the terrain. The smoothness factor affects the horizontalness of peaks and hollows. Contours are generated from the mesh file based on user specified major and minor intervals. A window (boundary) of any size or shape can be specified. The program estimates contours between the last data point and the boundary. Because Wescom creates and stores both the mesh and plot files, it is possible to change characteristics of the contour map without regenerating the mesh. The user also can plot the contour map any number of times without regenerating the mesh or contours.

Part II

Part II of the test consisted of duplicating the site design for an ADP building. The site design, roughly 450 by 600 ft, entailed a raised, irregular-shaped building pad, parking lot, service drive, drainage swale, drainage ditch, and access road. The software was tested on how well it could accurately reproduce the design solution and its respective earthwork volumes. The problem consisted of four drawing sheets. These sheets included the as-built paving and grading plan, site plan, utilities plan, and cross sections.

The surface data consisted of original contours and roughly 90 field elevations noted on the paving and grading plan. Although possible, it was found impractical to digitize existing contours using any of the software packages without a digitizing tablet large enough to minimize the number of times the

drawing needed to be moved. Original surface data were assembled by scaling northing and easting distances of field elevations and entering them manually through a text editor into a data file.

Wescom software allows the user to design surfaces or meshes. Using this feature, it is possible to create a design surface and compare it with the original surface. This comparison yields the amount of earth that needs to be added or removed from each area of the site, ultimately producing the most efficient distribution of surface material. The following steps explain the process used to reach this solution. They also show how Wescom can be used to produce other design data that may be required in a solution.

Step 1. Create a natural surface mesh from original surface data. This mesh is to be used for calculating final earthwork volumes from comparison with a final design mesh. It can also be used to calculate cross sections or profiles of the natural surface at any location and interval. It is possible to create a contour map and three-dimensional (3D) view from this mesh.

Step 2. Enter the northing and easting coordinates of the design features, coordinates to enter include the corner points of the building pad and parking lot as well as the centerline traverses of the ditch, swale, and road. These coordinates are used to define areas that will be given new elevations. They are also used to produce a site plan drawing if one is desired. The software can analyze this site plan and an annotated plan with any combination of bearings, distances, angles, areas, and lot numbers can be produced.

Step 3. Create a design mesh by giving the building pad, defined by corner coordinates and stored by Wescom as a lot file, the desired elevation. Slopes from the building pad to natural surface are specified. This mesh is now the base mesh for further design. A contour map or 3D view can be created if desired.

Step 4. Create a second design mesh by defining the elevation and slope of the drainage swale. It is possible to do this since the swale is at a constant slope. Side slopes of the swale to natural surface are specified. This mesh is now the base mesh for further design. Had the swale not been at a constant slope, it would have been necessary to first define a design profile and design template for it. Average end area volumes along the swale can be generated after defining a profile and template.

Step 5. Create a third design mesh by defining the elevation and slopes of the parking lot and service drive. Slopes from the edge of the lot and drive are defined. Different slopes along different edges are specified. A vertical slope is required along some edges. This mesh is now the base mesh for further design.

Step 6. Derive a surface profile and cross sections along the centerline of the drainage ditch using the third design mesh as a base. Create a design profile and template of the ditch and road. The ditch and road are defined as one template. Average end area volumes can be calculated for the ditch and road if desired. In addition, cross sections and profiles of the design surface can be plotted or data can be printed. The road and ditch template and profile data are then entered into a fourth and final design mesh. A final contour map and 3D view can now be plotted.

Step 7. Compare the final design mesh with the natural surface mesh and compute earthwork volumes. Enter bulking and compaction factors. The program then displays a grid overlay of volumes along with total cut and fill volumes.

Figures C1 through C4 are samples of the Wescom output for the test problem.

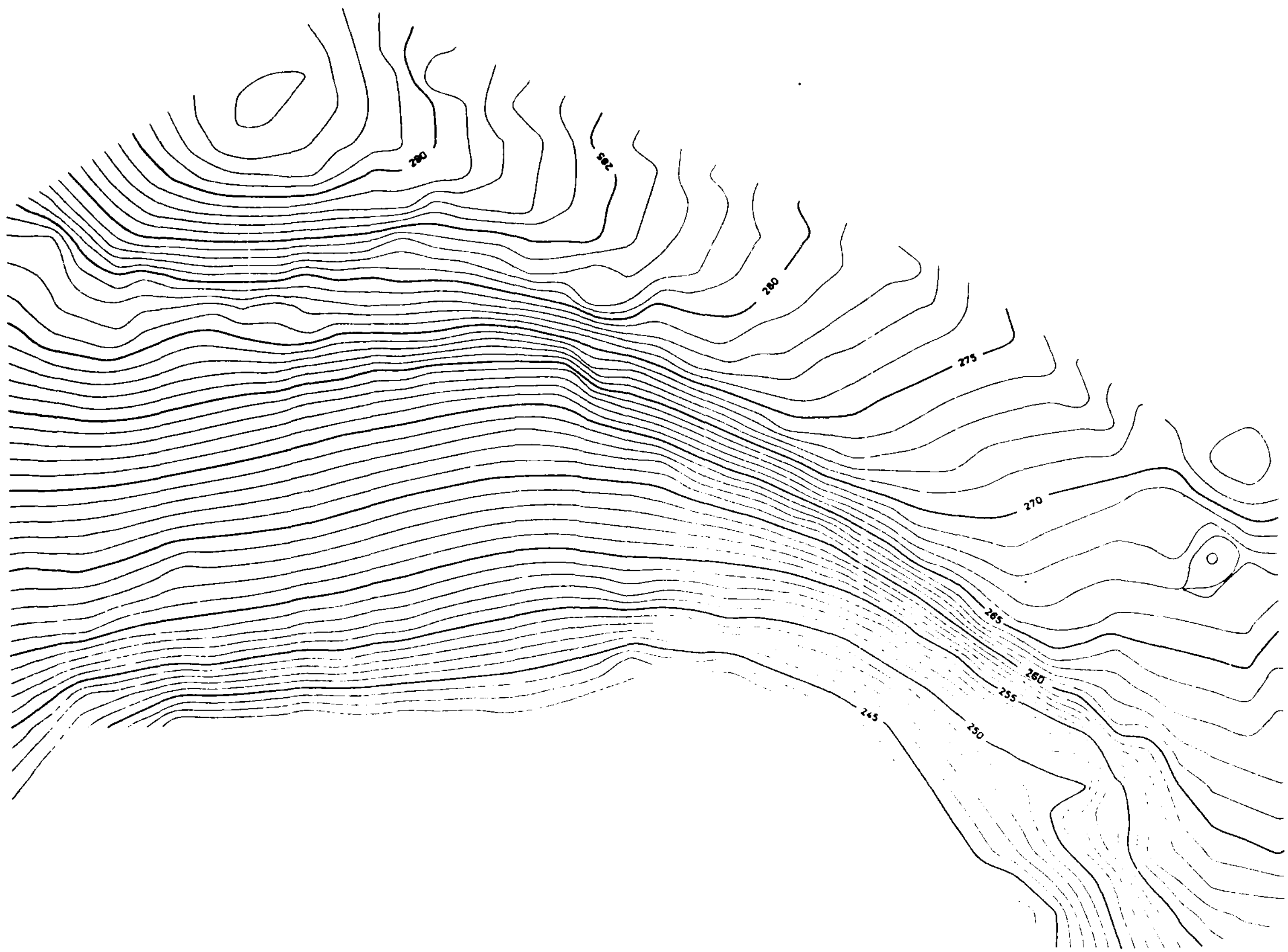

Figure C1. Seattle landslide project: Wescom software.

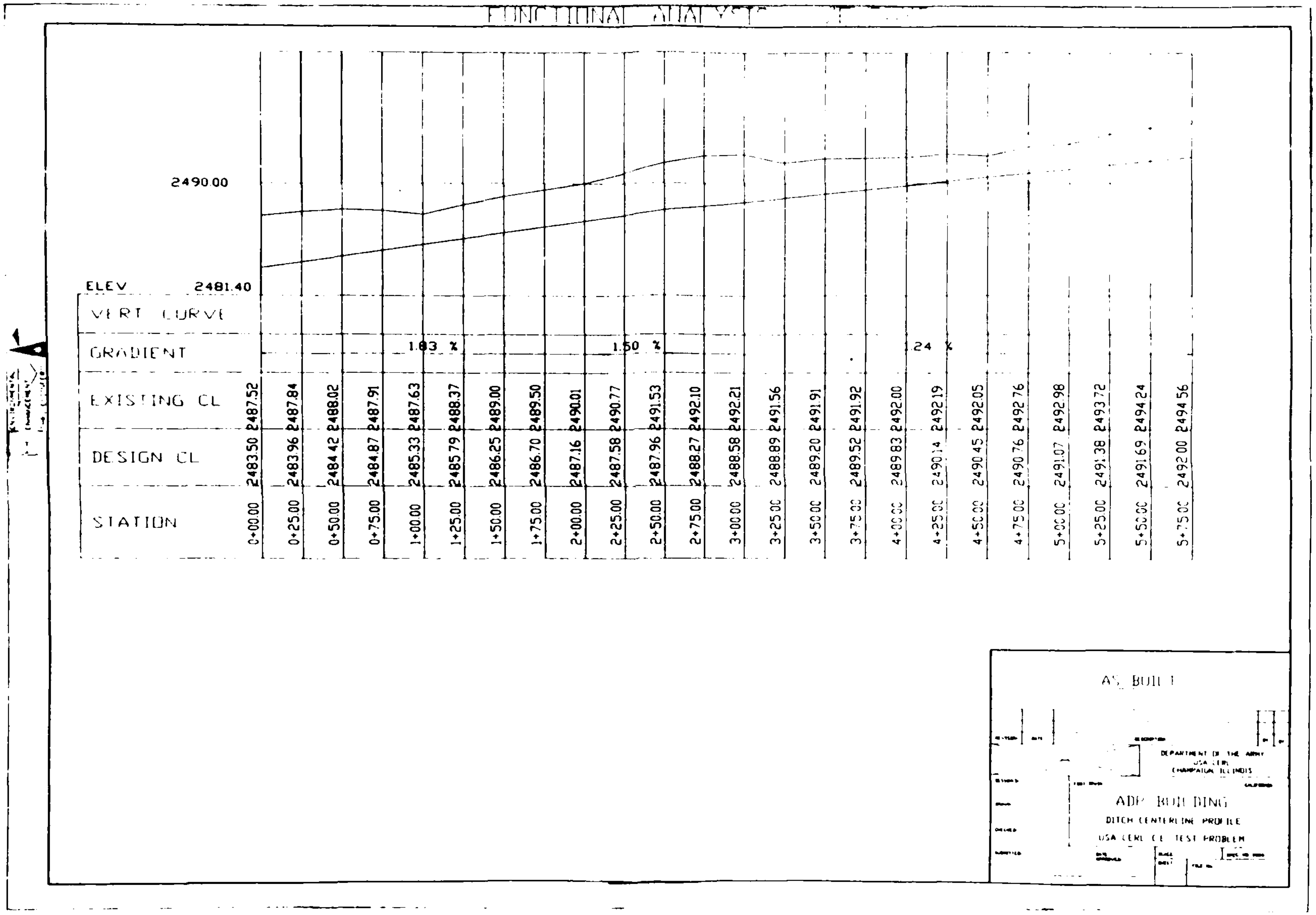

Figure C2. Ditch centerline and natural surface profile: Wescom software.

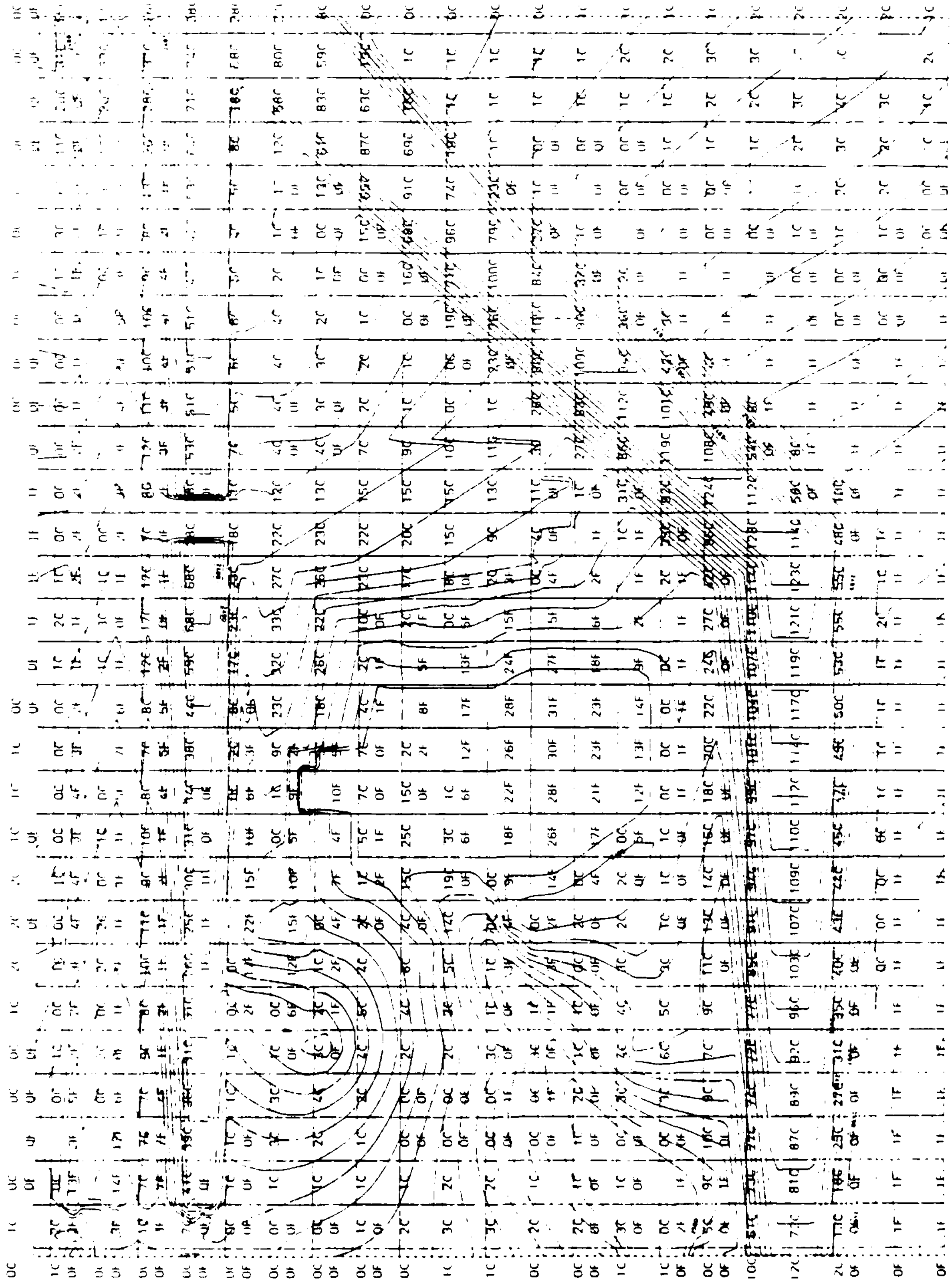

Figure C3. Design contours: Wescom software.

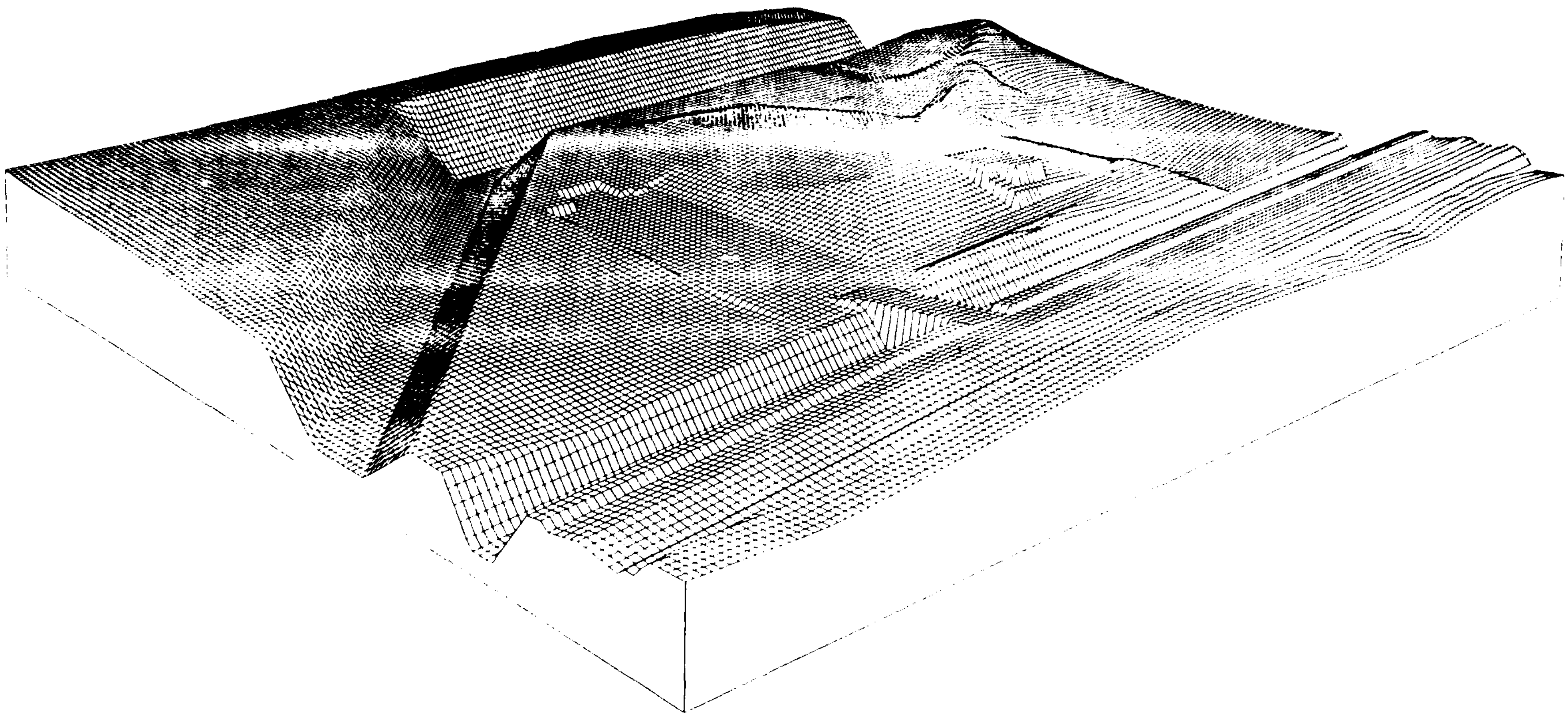

Figure C4. Perspective mesh final design: Wescom software.

Wescom, Posttest Updates

Below are Wescom enhancements, modifications, and new product releases since March 1988. This information has been provided by Wescom distributors to show software developments released after the deadline for benchmark testing.

Enhancements

1. Coordinate Geometry Module:

SUBI Addition of new subcommand (STOF)
Computes coordinates of a point given (1) a station location along a traverse and (2) the offset from the traverse.

SUBO Addition of new command (PRNSTOFF)
Computes and prints the station and offset values for selected points, having received or computed coordinate values, and given a traverse and a known station value on that traverse.

SUBO Enhancement of PLNUMAREAS command.
Lot descriptors can now be annotated on the plan.

2. Subdivisional Mapping Module:

SUANN Enhanced to annotate traverse lines (e.g., road centerlines).
Traverse lines (including curves) are annotated automatically.

SUANN Enhanced to enable labeling of curved and/or straight lines with a symbol that refers to dimensions shown in an annotation table (e.g., curve/line data tables).

3. Contouring Module:

MESH Significant improvement to computational speed without altering mathematical methods used in the program. A DTM can now be computed in approximately one-third the time required with previous versions of MESH.

MESH Enhanced to enable RIDGES command to handle any combination of POINTS, STRINGS, and RANGES subcommands. Previously, only one of these subcommands could be, used at any time to specify break lines in DTM generation.

MESH Enhanced to enable the user to specify the number of iterations for each mesh and the relaxation coefficient used during the iterations.

MESH The amount of data which can be handled has been greatly increased.
The maximum amount of data now handled include:

- 314,928 data points are possible (previously 32,767)
- 16,360 ridge segments can be specified
- 6550 ridge segments may be inside the mesh window.

MEUT Addition of new command (SURFACE).
Computes the true surface area of a mesh within any window. That is, the surface area increases as the slope of the mesh increases.

MEUT Significant increase to the computational speed of the MATH command involving two original meshes that have the same mesh limits and mesh intervals. The speed has been increased by a factor of at least 10.

MEUT Addition of new mathematical function to MATH command to create the minimum or maximum mesh from two meshes.

4. Site Grading Module:

MEDES Enhanced to enable the boundary of the design area to be anchored to the natural or existing surface.

5. Roads Module:

SEDES Template command enhanced to enable:

- Any point on a template to be tied to the natural surface elevation at that point ^U^
- Berms (benches) to be specified efficiently
- Points on the template to be defined by an elevation and a slope
- Points on the template to be defined by slopes from the previous and next points.

New Software Releases (as of June 28, 1988)

1. Adjustments Module:

SUTRV This is a survey traverse program that calculates 3D coordinates from field observations. Features:

- Compass, transit, crandall, and least squares adjustments
- Elevations computed and adjusted
- Side shots and side traverses from any traverse point
- Single or multiple angle readings
- Plot of traverses and sideshots generated
- Computed coordinates can be stored in Wescom database file
- Lots and traverses can be defined from traverse and side shot points and stored in a Wescom database file.

2. Roads Module:

SEUT This is an engineering utility program that converts station, offset, and elevation data to northing, easting, and elevation data. Features:

- Allows cross sectional data and string information to be input easily into the program MESH for generation of DTMS.
- Creates new horizontal alignments and natural surface cross sectional data by generating a DTM using the existing data.
- Allows cross sectional data and string information to be input easily into the program MEDES for generating design surfaces.

Projected Software Releases

1. Coordinate Geometry Module:

SUCOGO This is a new interactive coordinate geometry package. This program makes full use of interactive screen plotting and incorporates zooming and panning features. The program is mouse-driven.

2. Roads Module:

SENAT This program is currently being upgraded to enable natural or existing surface cross sectional data to be related to an offset survey baseline rather than the actual centerline.

3. Geodetic Module:

GETRAV Processing and adjustment of geodetic survey data including both traverses and radiations.

GEGRID Creation of a grid with geographic boundaries. Both a geographic and rectangular interior can be specified.

GEXFRM Transformation of data between geographic and rectangular coordinate systems.

GEIXF Conversion of coordinates between geographic and rectangular grid. Performs point-to-point computations in respective coordinate systems.

APPENDIX D:

CEAL SOFTWARE TEST

The CEAL software was tested using the version received as of March 20, 1988 (version 5.12). No attempt has been made to identify capabilities of products made available after that time or to predict future products and their features. Information from CLM/Systems, Inc. concerning product revisions and future capabilities is included at the end of this appendix. As noted in Chapter 4, CLM/Systems objected to many of the conclusions formed about its product. These rebuttals are noted where appropriate.

Part I

Phase I of the software test was divided into two parts, the first of which involved inputting electronic data from a floppy disk into the software package, creating a contour map, and comparing it with the existing contour map provided with the data. X, Y, Z data were provided along with point numbers and a point code, all in a fixed-field format.

Input

Data in the format provided for the test was not acceptable by CEAL. Before it could be accepted as data to be used in creating a random X, Y, Z model, it had to be rearranged and placed into the correct fields. Reformatting of data from a foreign source is normal procedure with this software. It was not possible to screen existing data by specifying "acceptable" ranges. Therefore, undesired point codes within CEAL had to be done manually after viewing plotted data on screen. CLM/Systems, Inc. responded to this finding by stating, "In CEAL all raw data can be ... processed by the TCheck command to screen data for the acceptable range."

Contours

CEAL creates a model file from X, Y, Z data input by the user, Carta software is used in conjunction with CLM to create a triangulation network from this random model file. The triangulation network, which can be stored as a (tin) file, is used to interpolate contours which are then stored as a contour model file. This model file can be altered, allowing the user to specify local high points or low points. The contour model can be used to create a contour plot file that can be stored or plotted. The user can specify any rectangular window as well as a border. The contour interval also must be specified. The user is permitted to specify any additional contour that he/she wishes to be plotted which may not fall on the contour interval. The contour map created by CEAL was found to be close to the one provided with the problem.

Part II

Part II of the test consisted of duplicating the site design for an ADP building. The site design, roughly 450 by 600 ft, entailed a raised, irregular-shaped building pad, parking lot, service drive, drainage swale, drainage ditch, and access road. The software was tested on how well it could accurately reproduce the design solution and its respective earthwork volumes. The problem consisted of four drawing sheets. These sheets included the as-built paving and grading plan, site plan, utilities plan, and cross sections.

The surface data consisted of original contours and roughly 90 field elevations noted on the paving and grading plan. Although possible, it was found impractical to digitize existing contours using any of the software packages without a digitizing tablet large enough to minimize the number of times the drawing needed to be moved. Original surface data were assembled by scaling northing and easting distances of field elevations and entering them manually into a data file.

CEAL software allows the user to produce "model" files from existing terrain and design data. A model file of one type, such as a random model file, can be used to produce another model type such as a contour model, which can then be used to produce cross sectional models. These models are stored as text files that the user can alter. The user can specify design templates and profiles which are used in conjunction with the original surface cross sections to compute average end area volumes. It is also possible to produce volumes from contour models using vertical average end areas between contours. In this way, the program computes the volume of a design surface created by the user through specification of design contours and compares this volume with that of the original surface. The following steps explain the procedure used in the ADP site problem.

Step 1. Create a random model from w, y, z data provided with the problem. Using Carta, create a triangulation network used as a basis for generating a contour model. This contour model can be used to create a plot file which can be stored or plotted. The triangulation model or contour model can be used to generate cross sectional data.

Step 2. Enter the northing and easting coordinates of the design features. Coordinates entered include the corner points of the building pad and parking lot as well as the centerline traverses of the ditch, swale, and road. These coordinates can be used as chains for construction of cross sections. They also can be used to produce a site plan drawing if one is desired. The plan can be annotated with distances, bearings, and areas, as the user wishes.

Step 3. Along the swale centerline, construct the natural surface cross sections from the triangulation (tin) model. Construct a design vertical alignment or design profile. Construct the design template to be used and the template variations to be included at the ends of transition areas. (In the case of the swale, there are to be no transition areas.) Using natural and design cross sections, the design profile, and user input bulking and compaction factors, compute the average end area cut and fill volumes.

Step 4. Repeat step 3 for the parking lot, service drive, access road, and drainage ditch. Areas in overlap are not accounted for.

Step 5. Prepare design contours for the ADP building pad manually. Construct a new contour model by entering new contour strings and elevations. Contour strings are entered as x, y distances from an index point. Note: the user must do all design work. It is not possible for USACERL to compute design slopes.

Step 6. Use the contour method to calculate the volumes of the original surface model and the new model with design contours. Compare and subtract the total volumes. Note: this method will produce total volumes but will not differentiate between real cut and fill volumes, nor will it produce specific areas of cut and fill. CLM/Systems' response to this finding was that "Incorrect procedure was used by reviewer. Invalid conclusions."

Figures Dl through D3 are samples of output obtained using the CEAL software in the test problem.

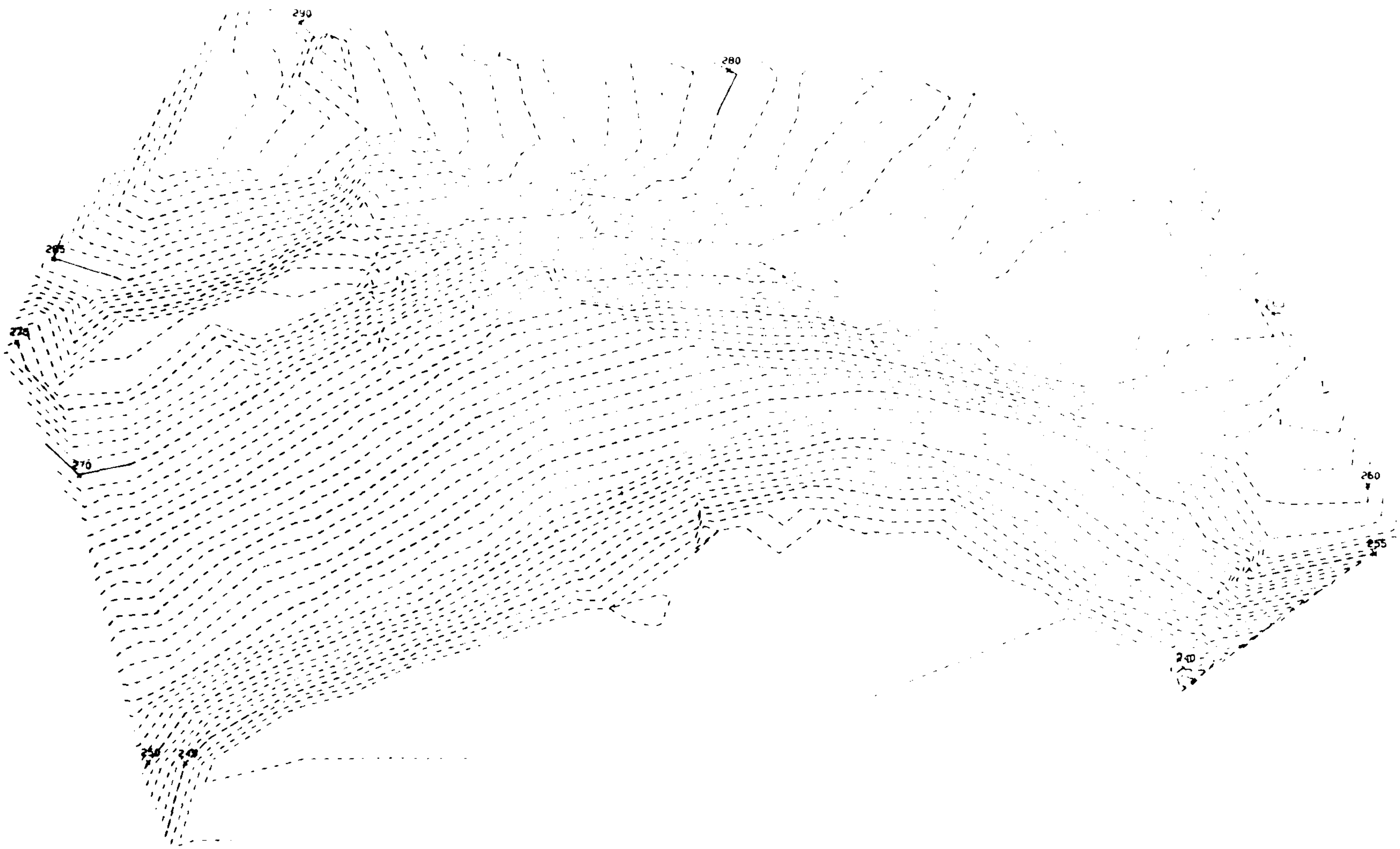

Figure D1. Seattle landslide project: CEAL software.

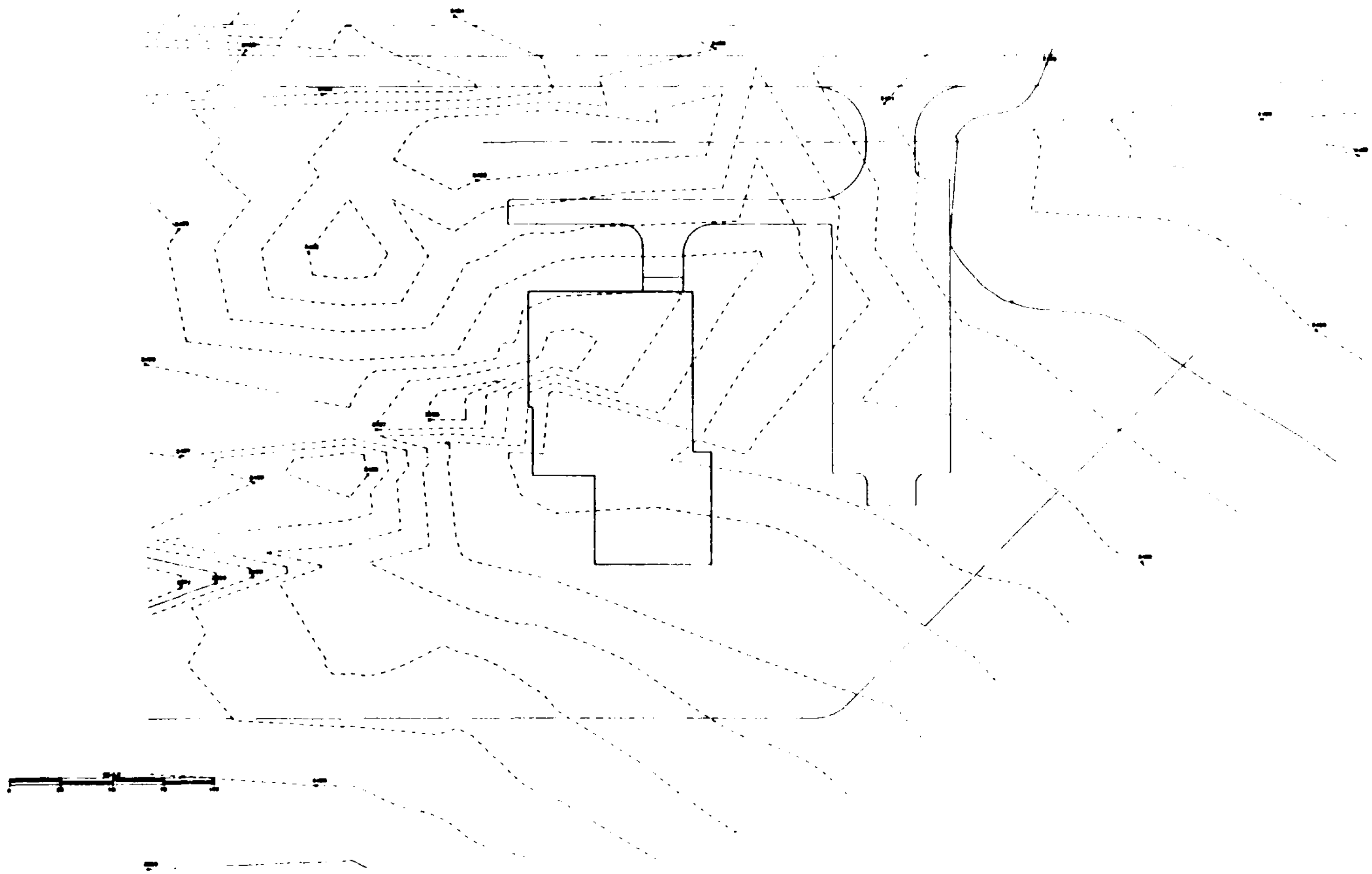

Figure D2. Coordinate geometry on natural surface contours: CEAL software.

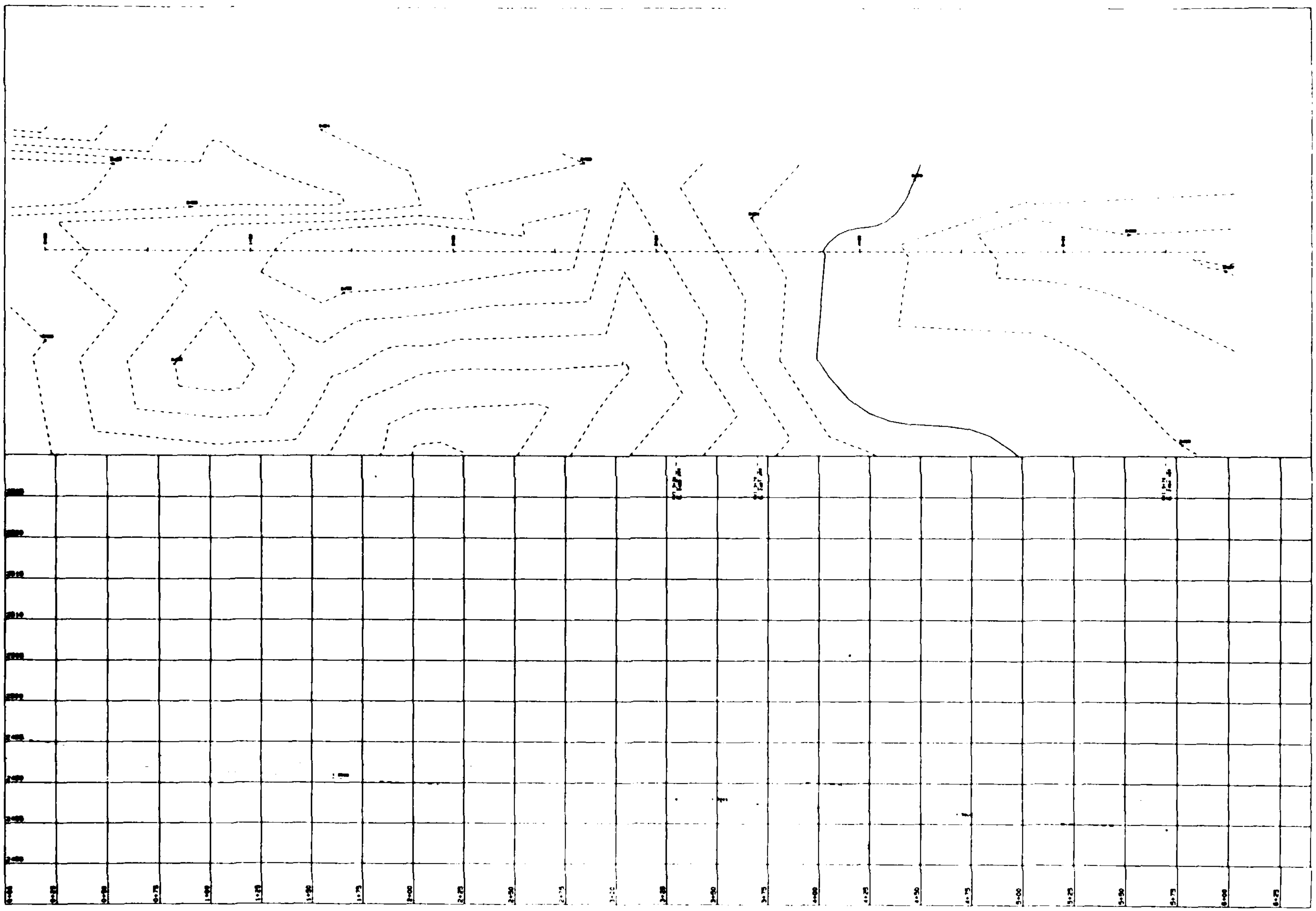

Figure D3. Ditch centerline and natural surface profiles: CEAL software.

CEAL Posttest Updates

According to CLM/Systems, enhancements, modifications, and new product releases since March 1988 have had an enormous impact on CEAL's procedures and applications. For example, the various model files (i.e., random, contour, overlay) in the version tested are consolidated in the current version of CEAL into a single model type—a Universal Digital Map Model.

APPENDIX E:

CivilSoft SOFTWARE

The CivilSoft software was tested using the update received as of March 20, 1988. The versions tested were COGO-PC PLUS version 2.00, Contour version 3.00, Digiplus version 2.00, and HDP version 1.01.

Part I

Phase I of the software test was divided into two parts, the first of which involved inputting electronic data from a floppy disk into the software package, creating a contour map, and comparing it with the existing contour map provided with the data. X, Y, Z data were provided along with point numbers and a point code, all in a fixed-field format.

Input

Because of its format, the data provided for the test had to be altered before being entered into CivilSoft. The data had to be rearranged to match CivilSoft's format specifications. Point codes had to be deleted from the data set. This problem could have been alleviated by using CivilSoft's Collect package. However, USACERL did not test this package. CivilSoft allows screening of easting, northing, and elevation data; however, it was not possible to omit undesired data based on point codes.

Contours

CivilSoft creates a triangulation network from which contours can be interpolated. The triangulation network uses only data points that are input, so no intervals need to be specified. The major and minor contour intervals can be specified as well as a title and border. CivilSoft allows rectangular windowing, but not polygonal. Contours are generated only inside the data field. The contour map created by CivilSoft was found to be close to the original provided with the problem. CivilSoft stores neither the triangulation model nor the contour map as files. Therefore, the triangulation model must be regenerated each time a change in contour intervals is desired and whenever the contour map is plotted.

Part II

Part II of the test consisted of duplicating the site design for an ADP building. The site design, roughly 450 by 600 ft, entailed a raised irregular-shaped building pad, parking lot, service drive, drainage swale, drainage ditch, and access road. The software was tested on how well it could accurately, reproduce the design solution and its respective earthwork volumes. The problem consisted of four drawing sheets: the as-built paving and grading plan, site plan, utilities plan, and cross sections.

The surface data consisted of original contours and field elevations noted on the paving and grading plan. Although possible, it was found impractical to digitize existing contours using any of the software packages without a digitizing tablet large enough to minimize the number of times the drawing needed to be moved. Original surface data were assembled by scaling northing and easting distances of field elevations and entering them into a data file manually.

CivilSoft software allows the user to design templates and profiles along linear design surfaces. It can then produce cross sections and calculate average end area volumes. By this method, it is possible to produce cut and fill volumes for portions of the test problem. However, total cut and fill volumes and a mass haul diagram cannot be produced using CivilSoft because of its inability to calculate volumes for nonlinear design surfaces such as irregular-shaped building pads. The following steps explain the process used to produce average end volumes along with other design data that may be required in a solution.

Step 1. Input original surface data to produce a triangulation network from which a contour map and 3D view can be created.

Step 2. Enter the northing and easting coordinates of the design features. Coordinates to enter include the corner points of the building pad and parking lot as well as the centerline traverses of the ditch, swale, and road. These coordinates are used to produce a site plan drawing if one is desired. The software can analyze this site plan and produce an annotated plan with distances, bearings, and areas.

Step 3. Calculate natural surface cross sections along the swale centerline by scaling the contour map. Define a design profile and template. Produce average end area volumes, cross sections, and cross sectional data.

Step 4. Calculate the natural surface cross sections along the parking lot and service drive centerline manually. Define design profiles and templates. Produce average end area volumes, cross sections, and cross sectional data.

Step 5. Calculate the natural surface cross sections along the drainage ditch/access road centerline manually. To obtain accurate total volume quantities, you must remember to account for the change in natural surface due to overlapping templates. That is, you must account for the change in the natural surface cross section where the catch points for the drainage ditch template are changed because of the service drive. Define a design profile and template for the drainage ditch/access road. Produce average end area volumes, mass haul diagram, cross sections, and cross sectional data.

Figures El through E3 are samples of the output obtained using CivilSoft in the test problem.

CivilSoft Posttest Updates

Below are CivilSoft enhancements, modifications, and new product releases since the March 1988 benchmark testing.

Contours: the new CivilSoft Contour Plus Software Program will store the triangular model or contour map as a file.

Licensing Agreement: hardware locks are "no longer required for use with these software programs.

A new package called Site Design Program (SDP) will be released in August 1988. This program is best suited for the situation described in part II of the benchmark test.

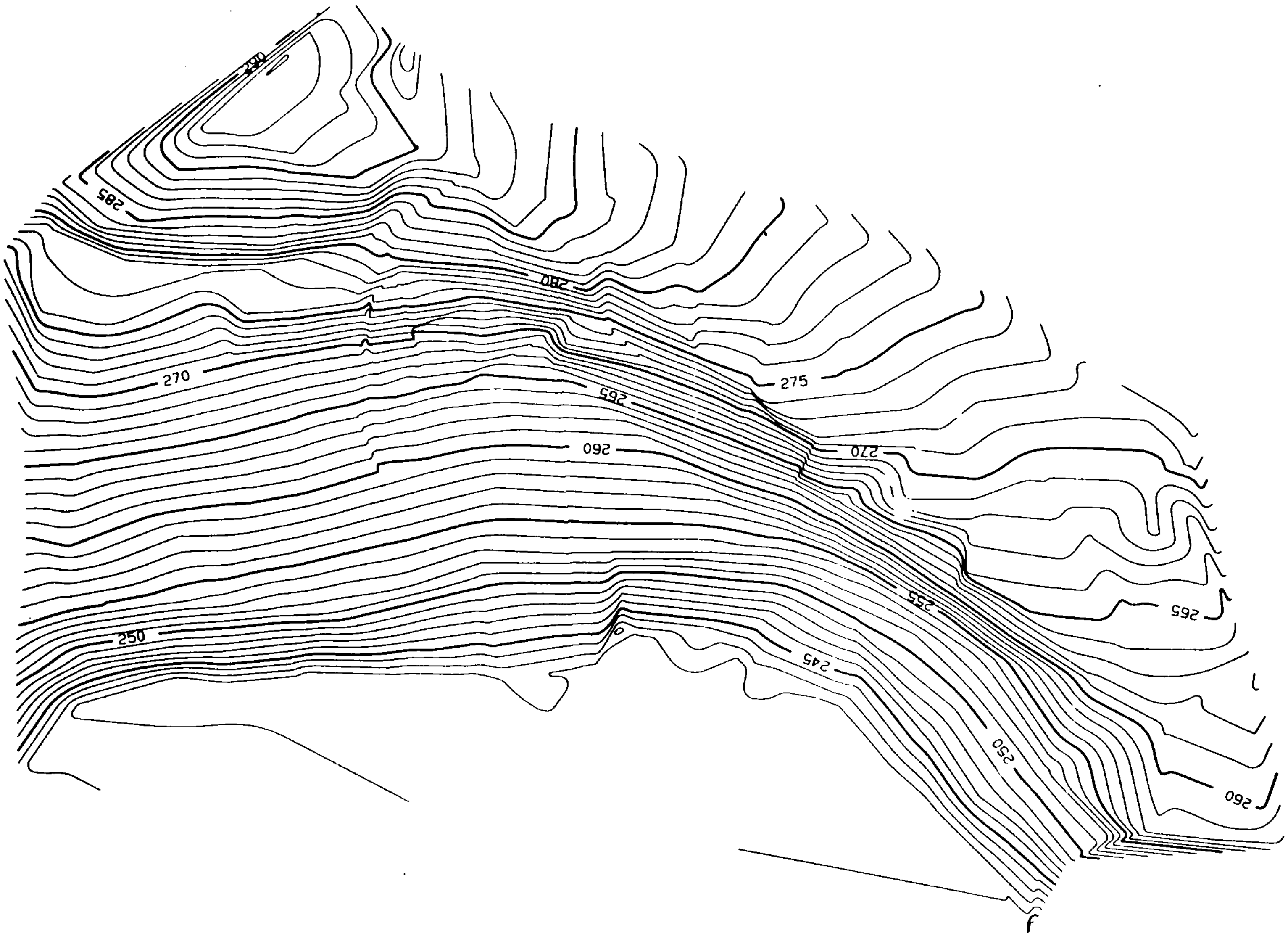

Figure E1. Seattle landslide project: CivilSoft software.

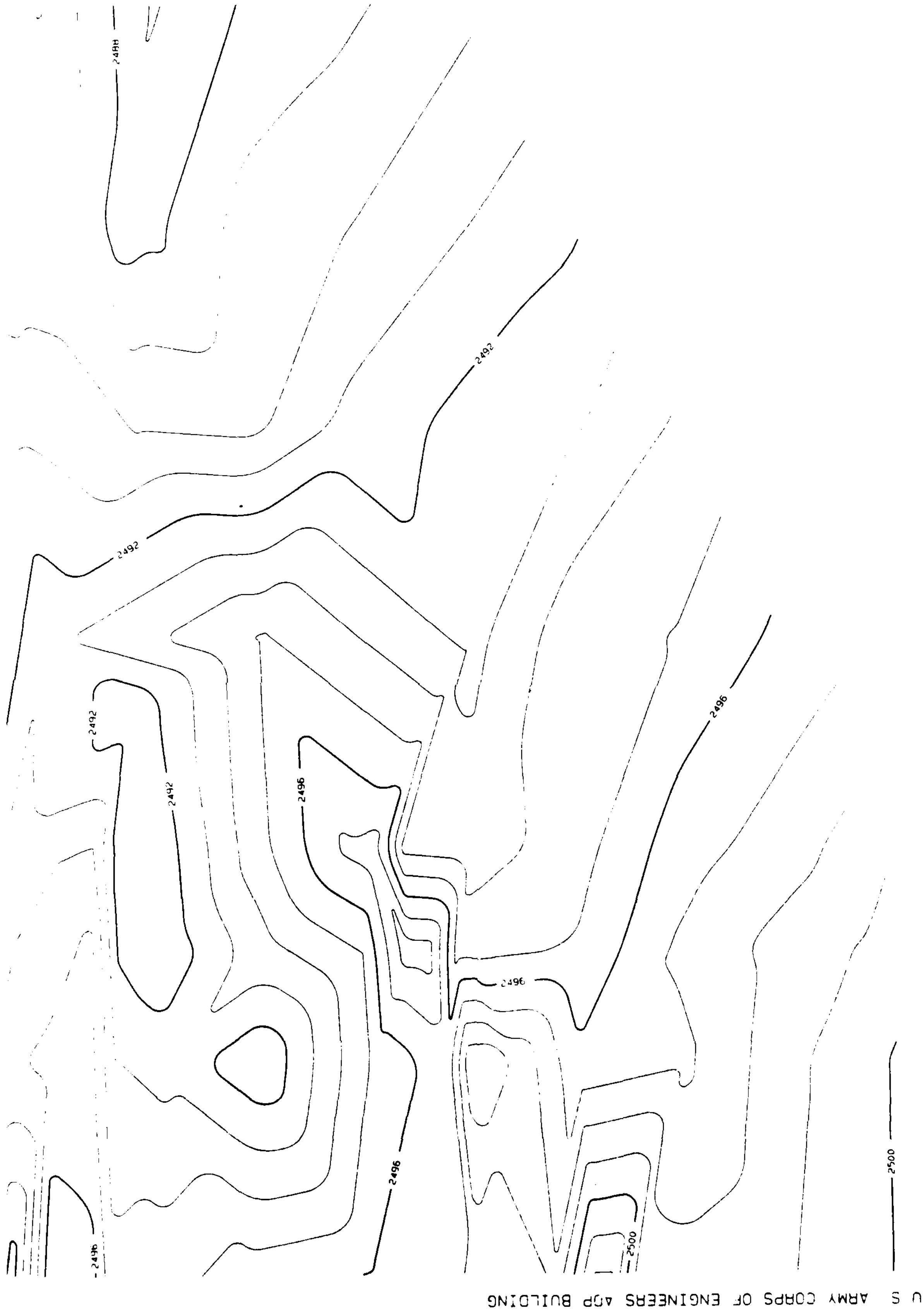

Figure E2. Natural surface contours: CivilSoft software.

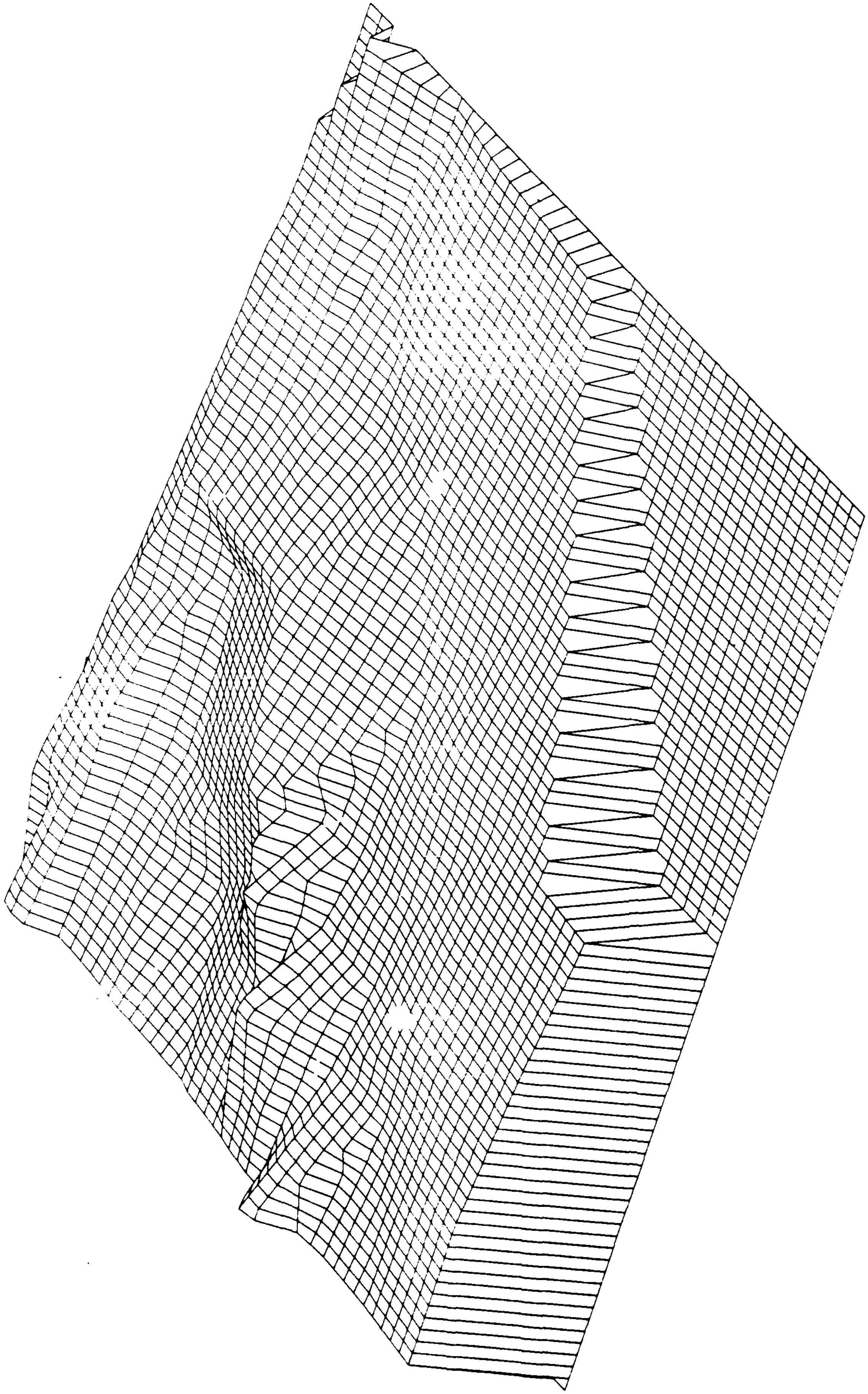

Figure E3. Natural surface perspective mesh: CivilSoft software.

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